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FOREST COMMUNITIES IN A NATURAL SITE AT UNION HILL, AND COMPARISONS WITH OTHER FORESTS IN ILLINOIS

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ABSTRACT.—Plant studies were made in the Union Hill Natural Area, located near Belleville, Illinois. From 27 plots found along four transects frequency, density and basal area data were collected for tree species only. Terrace, slope, and upland communities were sampled, and the relationships of these plots were compared by an ordination scheme. The basal area data were compared with two northern Illinois upland tree communities and with five southern Illinois terrace, slope, and upland communities. Comparison ordination is a valid method for the study of different communities within a floristic region.

Man is destroying many areas of natural vegetation, which makes it imperative that we hasten to describe what is left of natural communities in the world. If such work is not speedily completed, we may soon find several important links missing in the mosaic of communities. Such omissions will make it difficult to explain ecological patterns of those natural communities which remain.

Much of the previous work in descriptive plant ecology has presented communities as discrete ecological units. This is a gross over-simplification. Nearly fifty years ago Gleason (1926) proposed that, inasmuch as each plant species had environmental requirements different from those of every other species, the classification of plant communities into separate and distinct associations was inadequate. Following Gleason's concept a number of ecologists have shown vegetational gradients based on a direct analysis of the vegetation itself. Some of these studies were made by Gleason (1922), Cain (1935), Curtis and McIntosh (1951), Brown and Curtis (1952), Goodall (1954), Bray and Curtis (1957), Clausen (1957), McIntosh (1957), Lindsay *et al.* (1961), Weaver (1961), Monk (1965), Kumler (1969), and Geideman and Kumler (1972). The concept has also been used by animal ecologists in community gradient studies of insects by Whittaker (1952), Kato *et al.* (1955), of copepods by Whittaker and Fairbanks (1958) and of birds by Bond (1957), and Beals (1960). The Union Hill investigation shows vegetational gradients based on a quantitative analysis.

One of the aims of ecological probes should be information of floristic regions. How, for example, does the Union Hill vegetational composition compare with other parts of the oak-hickory climax region? On a less ambitious scale, an attempt was made to fit investigations of forest communities in Illinois into a system to understand better this floristic sphere. The ordination techniques of Bray and Curtis (1957), Beals (1960), and Clausen (1957) were used on data taken from the literature. The Brownfield Woods (Boggess and Bailey, 1964) and Clark County (Ebinger and Parker, 1969) investigations were considered as representative of northern Illinois. The Lusk Creek (Ashby, 1968) and Shawnee National Forest (Geideman and Kumler, 1972) studies were regarded as portraying the vegetation of southern Illinois.

Description of the Study Site

The Union Hill Natural Area was studied because it is one of the few remaining relatively undisturbed sites in this part of Illinois. It is a tract of privately owned land five kilometers from Belleville, Illinois, surrounded by homes on small tracts of land to the north, a quarry of the Hill Brick company to the west, and open farm land to the south and east. It is not only threatened by the increasing pressure from housing, but also by increasing air and water pollution. For a number of years garbage and trash have been dumped on the north side of a stream that flows through this tract (Figure 1). At present, the road leading to the quarry has been closed to wheeled traffic, which has materially reduced the solids pollution. The stream is highly polluted from strip mine acids as well as from the urban solid wastes. Yet the steep bank of this stream has protected the forest from the main destructive activities of man.

This forested area consists of 30 hectares in a 97 hectare area. (Figure 1). A narrow terrace about two meters in elevation above the level of the creek bed is found parallel to this stream. A slope rising rather abruptly from the terrace leads to a somewhat flattened ridge of upland vegetation approximately 18 meters above the terrace. Three drainage areas from the upper ridge cut through the study site. These depressions are usually dry during the summer months and handle mostly surface water, although water runs continuously throughout the winter months when there is more rainfall.

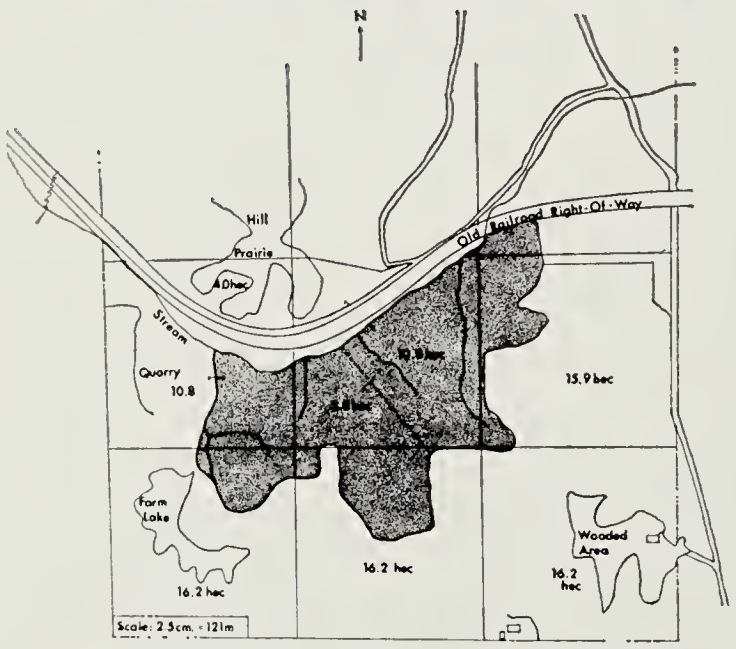

Figure 1. Map of the Union Hill Natural Area showing roads, streams, and drainage area, as well as the location of the study site.

Study Methods — Field Data

Work was begun in the fall of 1965, with a preliminary survey of the area. Vegetational data were collected the following spring and also at several later times up to the spring of 1970.

Within the Natural Area four transects were established. The beginning point of three of these transects was on the terrace near the stream. Plots were sampled upward toward the top of the nearby ridge. A fourth transect was located parallel to the creek, entirely within the terrace zone. Because the terrace is quite narrow, it was necessary to add this fourth transect to obtain a representative sample of the terrace vegetation.

From center points located at six meter intervals along the transect three nested plots were set up: circular plots with a 5.64 meter radius (0.01 hectare) for tree species; square plots two by two meters square for shrubs; and plots one by one meter square for herbaceous plants. The number of plots per transect varied with the elevation of the ridge, the steepness of the slope, and the varying width of the creek terrace. Most of the data collected were concerned with tree species, but the somewhat typical shrub and herbaceous understories were noted. A total of 27 plots were sampled as typical of the Union Hill site.

TABLE 1.—Importance Values of twenty-seven plots found in the Union Hill Study Area

Species	Plot Numbers[1]																										
	3	2	6	5	1	10	9	4	7	8	23	20	18	21	22	13	19	24	14	11	26	17	25	16	27	15	12
Hickory spp.			31			45					61	140	111			133	118	66	87	131	62	67	49	71	85	97	65
White oak § group §					34			81	35			33	189	150	151	85		59			99	80	84	114	118	102	63
Red, Black § oak gr. §						29	110		37	75	71	33		150	149		100	62	67	79	93	153	86	115	59	101	64
Dogwood			57	39			65	52		63	19	19				41	33	28	47	45					38		40
Ash spp.		31		59	29	37		67	37	67		21							60	45			50				28
H. Chestnut											22	27				41											40
Black Cherry											105							85			46		31				
Red Maple	82	41	33	84	29			100											39								
Sugar Maple											22	27															
Silver Maple																					49						
Sycamore	74	122			107				62	95																	
Elm. spp.			102	46	35	32			59																		
Buckeye	50	41			28	27			31																		
Black Walnut	94	32		72					39																		
Basswood						95																					
Hackberry		33			38																						
Sour gum			77																								
Persimmon							125																				
Ky. coffee tree						35																					
Totals	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300

1. Arranged according to X- and Y-axes ordination

TABLE 2.—Vegetation List of Tree Species found in Four Areas of Illinois Being Compared

Species	Common name	Areas				
		B	C	L	UH	SF[1]
Hickory Group:						
Carya ovata (Mill) K. Koch	Shagbark hickory	X	X	X	X	X
C. cordiformis (Wangenh.) K. Koch	Bitternut hickory	X	X	X	X	X
C. glabra (Mill) Sweet	Pignut hickory		X	X	X	
C. laciniosa (Michx. f.) Loud	Kingnut hickory			X		
C. tomentosa Nutt.	Mockernut hickory		X	X	X	
C. ovalis (Wang.) Sarg.	Oval hickory			X		X
White oak group						
Quercus alba L.	White oak		X	X	X	X
Q. macrocarpa Michx.	Bur oak	X		X		X
Q. muehlenbergii Engelm.	Chinquapin oak	X		X	X	X
Q. stellata Wangenh.	Post oak			X	X	X
Q. palustris Muench.	Pin oak		X			X
Red, Black oak group						
Q. rubra L.	Red oak	X	X	X	X	X
Q. imbricaria Michx.	Shingle oak	X	X	X	X	
Q. coccinea Muench.	Scarlet oak			X	X	X
Q. falcata Michx.	Southern red oak			X		X
Q. marilandica Muench.	Blackjack oak			X		X
Q. shumardii Buckl.	Shumard oak			X		
Q. velutina Lam.	Black oak		X	X	X	X
Cornus florida L.	Dogwood		X	X	X	X
Ash species						
Fraxinus americana L.	White ash	X	X	X	X	X
F. quadrangulata Michx.	Blue ash	X				
F. profunda (Bush) Bush	Red ash				X	
Castanea dentata (Marsh.) Borkh.	Horse chestnut				X	X
Prunus serotina Ehrh.	Black cherry	X	X	X	X	X
Acer negundo L.	Box elder			X	X	X
A. rubrum L.	Red maple			X	X	X
A. saccharum Marsh	Sugar maple	X	X	X	X	X
A. saccharinum L.	Silver maple				X	X
Platanus occidentalis L.	Sycamore	X	X	X	X	X
Elm species						
Ulmus alata Michx.	Winged elm			X		X
U. americana L.	American elm	X	X	X	X	
U. rubra Muhl.	Slippery elm	X	X	X	X	X
Aesculus glabra Willd.	Buckeye	X		X	X	
Juglans nigra L.	Black walnut	X	X	X	X	X
Tilia americana L.	Basswood	X	X	X	X	X
Celtis occidentalis L.	Hackberry	X	X	X	X	

TABLE 2.—Continued

Species	Common name	Areas				
		B	C	L	UH	SF[1]
Nyssa aquatica L.	Sour gum (Tupelo)				X	
Diospyros virginiana L.	Persimmon		X		X	X
Gymnocladus dioicus (L.) Koch	Kentucky coffee tree	X			X	X
Salix nigra Marsh	Black willow					X
Populus deltoides Marsh	Cottonwood					X
Alnus serrulata (Ait.) Willd.	Common alder					X
Betula nigra L.	River birch			X		
Carpinus caroliniana Walt.	American hornbeam		X	X		X
Fagus grandiflora (Ehrh.)	Beech		X	X		X
Gleditsia triacanthos L.	Honey locust	X		X		X
Liquidambar styraciflua L.	Sweet gum			X		X
Liriodendron tulipifera L.	Tulip tree			X		X
Nyssa sylvatica Marsh	Black gum		X	X		
Sassafras albidum (Nutt.) Nees	Sassafras		X	X	X	X
Juniperus virginiana L.	Red cedar			X		X
Crataegus mollis Scheele	Downy hawthorn	X				
Asimina triloba (L.) Dunal	Pawpaw	X				X
Lindera benzoin (L.) Blume	Spicebush	X				
Staphylea trifolia L.	Bladdernut	X				X
Ostrya virginiana (Mill.) K. Koch	Hop hornbean (ironwood)	X	X	X		X
Juglans cinerea L.	Butternut		X	X		X
Cercis canadensis L.	Redbud	X	X		X	X
Morus rubra L.	Red mulberry		X			
Total species per location		25	28	42	32	43

[1] B = Brownfield Woods
C = Clark County
L = Lusk Creek
UH = Union Hill
SF = Shawnee National Forest

Frequently, density, and basal area data were collected for the tree species. Woody plants over 3.2 meters in height and 10 centimeters in diameter were considered trees. The oak trees were not separated by species, but rather were considered as two groups of oaks — leaves without bristle tips and with acorns maturing at the end of one season or the white oak group; and leaves with bristle tips and with acorns maturing at the end of two seasons or the red-black oak group (Fuller, 1949). Species of elm, ash and hickory were also grouped when collecting the data (Table 2).

Elm and ash are minor constituents of this forest community, contributing only 3.3 and 6.5 percent respectively of the importance values. The hickory and oaks, on the other hand, contributed 50.2 percent of the importance values. Four species of hickory were found. Two of these species were the dominents — shagbark and bitternut. Within the white oak group there were only three species in the study site. Of these white oak was the dominent. Within the red-black oak group four species were found. Here, the red oak (*Quercus rubra* L.) and black oak (*Q. velutina,* Lam.) were domi-

nent. It is difficult to identify oak species which may contain from 15 to 20 naturally occurring hybrids. The grouping of species does not detract from the precision of the results when there were so few species found and those identified were clearly dominents. Thus, all the oak, hickory, elm and ash species were grouped.

Study Methods — Data Analysis

The Importance Value (IV) (Curtis and McIntosh, 1951) was calculated for each of the tree species (Table 1). Once the importance of the species within the plots is established, the similarities of communities can be determined. The relationship of communities is measured by various indices of similarity or coefficients of community. These indices are used to show a distance between communities in a spatial pattern related to their ecological similarity. The most widely used similarity index in ordination procedures is attributed to several individuals. It is here called the Kulczynski index (McIntosh, 1967). Its most common expression is $\frac{2w}{a+b}$ where a is the sum of the quantitative measures of the species in one community, b is the sum for a second community, and w the sum of the lesser values for the species present in both communities.

Each plot of the transect was compared to each of the other plots. A matrix was constructed showing the coefficient of community for each of the plots compared to each of the other plots. Since the ordination of these plots attempts to arrange these stands according to their relative dissimilarity, inverse values of the coefficients of similarity were used, subtracting each value from 0.85. A value of 0.85 was chosen rather than 1.00, because in sampling one stand several times, the coefficient of similarity averages around this figure (Beals, 1960). This means that two stands with a similarity of 0.85 should probably be considered essentially identical. Two stands with nothing in common would then be 85 units apart. The sum of the inverse values with the highest number was considered the stand most different from the others and became reference stand a with a value of O. Conversely, the stand with the lowest sum of inverse values was considered to have the least in common with the first reference stand and became reference stand b. The length of the axis of an ordination is equal to the dissimilarity of the two selected reference stands.

The positions of the samples along the first of X-axis were calculated according to the method described by Beals (1960), using his formula $X=\frac{L^2+Da^2-Db^2}{2L}$ where L is the length of the axis (dissimilarity between reference plots a and b), and Da and Db are the dissimilarities of a given sample from the reference samples. This formula locates the sample by projection of the point of arc intersection onto a line between samples a and b.

The first reference sample (c) of the second or Y-axis is the sample having the highest e value or the sample which fits the X-axis least satisfactorily ($e^2=Da^2-x^2$). The second reference sample (d) of the Y-axis is chosen so that the line cd (Y-axis) is approximately perpendicular to the X-axis (line ab). Reference samples e and f for the third or Z-axis were not needed in this ordination.

Results and Discussion — Vegetation

A total of 32 tree species were found in the study sites along the four transects (Table 2). The results of the ordination made are plotted in Figure 2. Plot 3 at O is the first re-

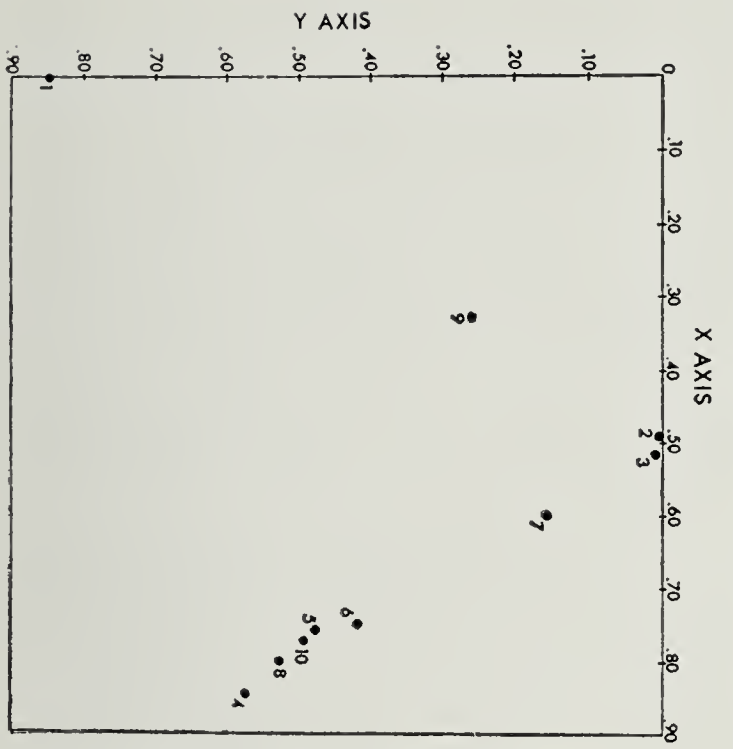

FIGURE 2. X- and Y-axis ordination of twenty-seven plots sampled at Union Hill. Reference point a on the X-axis and c on the Y-axis equal 0. Reference point b on the X-axis and d on the Y-axis equal 0.85. Plot 3 and plot 12 are the reference samples on the X-axis. Plots 2 and 12 are the reference samples on the Y-axis.

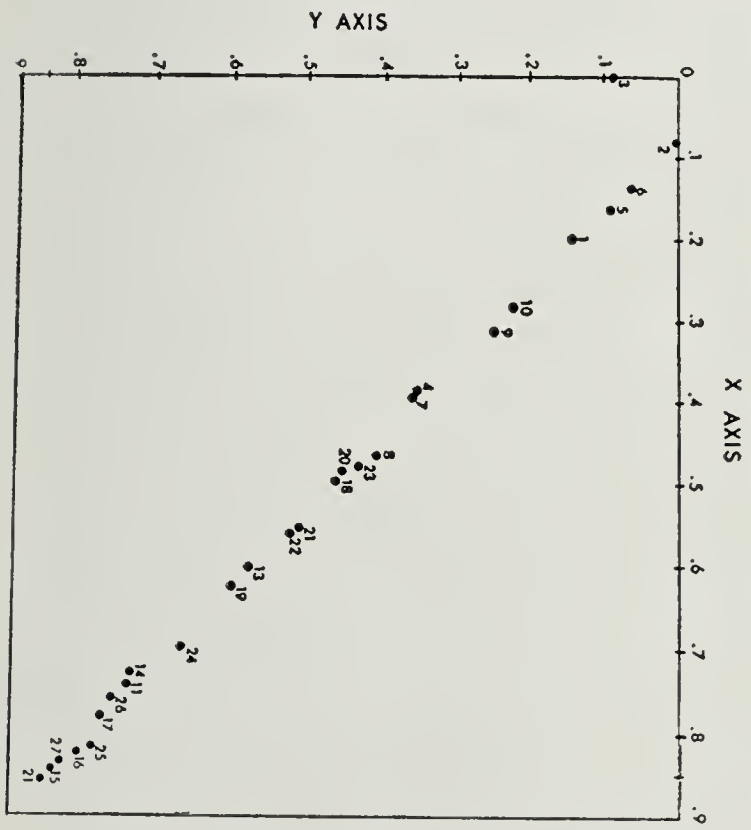

FIGURE 3. X- and Y-axis ordination of ten forest communities. Represented are terrace, slope, and upland areas found in the northern, central and southern parts of Illinois. (Numbers refer to community location as listed in Table 5).

ference stand (a) on the X axis. Plot 12 is the second reference stand (b) on the same axis and is 85 units away from Plot 3. Plot 2 at O on the Y axis (c) and Plot 12 at 0.85 (d) are the most dissimilar plots. The X and Y values as coordinates show the spatial relationships between the stands. Plots 1 through 10 were sampled within the creek terrace. Their ordination or relationship with each other is 2, 3, 6, 5, 1, 10, 9, 4, 7, and 8. The remaining 17 plots sampled were located on slopes and upland. It is apparent from these results that there was no validity in any assumption that the vegetation of all plots of the terrace was greatly different from slope and upland vegetation. In fact, the X and Y values of plot 8 within the terrace are very close to that of plot 23, which is located in the upland area. Plots 11 through 20 were located on slopes, while plots 21 through 27 were found in the upland of the Union Hill ridge.

The dominant species of trees growing at Union Hill are those found widespread throughout Illinois. Twenty-three species of trees were found on the terrace. The dominants of this site along the creek were two ash species (white and red), red maple, two species of elm (American and slippery), dogwood, red oak and white oak. Other species not found outside the terrace were buckeye, black walnut, hackberry, sour gum, persimmon, basswood, Kentucky coffee tree, redbud, sassafras and box elder. Most of the red maple growing in this location is found on the terrace.

Dominant trees found on the slopes and upland were white and red oak, shagbark and bitternut hickory, silver and sugar maple, horse chestnut, and black cherry. Trees from the terrace such as white and red ash, red maple, and dogwood are found in

these plots but in decreasing numbers. White and red oak as well as shagbark and bitternut hickory, dominants of the upland, were also found scattered throughout the terrace along the stream (Table 1).

The shrub understory of the terrace consisted of hickory species, oaks of both the bristle and non-bristle tip leaved groups, elm and ash species, cottonwood, box elder, sassafras, redbud, mulberry, sour gum, buckeye, and wild grape. These dominants of the shrub understory correlated well with the dominant trees. There appears to be no problem of forest regeneration in this area, if this forest is left undisturbed. The lowland species of shrubs such as cottonwood, elms, box elder, mulberry, sour gum, buckeye, sycamore, basswood, hackberry, persimmon, and Kentucky coffee tree were not found on the upland sites. Horse chestnut, black cherry, sugar and silver maple were found almost exclusively at higher elevations. A list of the main shrub species is found in Table 3. The Latin names are taken from Gray's Manual (Fernald, 1950) and Little (1953).

The main herbaceous plants varied with the seasons. A list of those plants observed and collected is shown in Table 3. In addition, there were a number of different mosses and lichens in a few areas where rock outcrops were present.

TABLE 3.—Vegetation List of Shrubs and Herbaceous Plants Found In the Understory of the Union Hill Plots

Shrubs	
Acer negundo L.	Box elder
Aesculus glabra Willd.	Buckeye
Carya cordiformis (Wangenh.) K. Koch	Butternut hickory
C. glabra (Mill) Sweet	Pignut hickory
C. ovata (Mill) K. Koch	Shagbark hickory
C. tomentosa Nutt.	Mockernut
Castanea dentata (Marsh.) Borkh.	Horse chestnut
Cercis canadensis L.	Redbud
Cornus florida L.	Dogwood
Fraxinus americana L.	White ash
F. profunda (Bush) Bush	Red ash
Morus rubra L.	Mulberry
Populus deltoides Marsh.	Cottonwood
Quercus alba L.	White oak
Q. macrocarpa Michx.	Bur oak
Q. muehlenbergii Engelm.	Chinquapin oak
Q. stellata Wangenh.	Post oak
Q. rubra L.	Red oak
Q. imbricaria Michx.	Shingle oak
Q. velutina Lam.	Black oak
Sassafras albidum (Nutt.) Ness.	Sassafras
Ulmus alata Michx.	Winged elm
U. americana L.	American elm
U. rubra Muhl.	Slippery elm
Vitis palmata Vahl.	Wild grape

TABLE 3.—Continued

Herbaceous	
Adiantum pedatum (L.) Planch.	Maidenhair fern
Arisaema dracontium (L.) Schott	Green dragon
A. triphyllum (L.) Schott	Jack in the pulpit
Asarum canadense L.	Wild ginger
Capsella bursa-pastoris (L.) Medic	Shepherd's purse
Carex amphibola Steud.	Sedge
Cerastium nutans Raf.	Mouse ear chickweed
Claytonia virginica L.	Spring beauty
Convallaria majalis L.	Lily of the valley
Desmodium glutinosum (Muhl.) Wood	Beggar's tick
Dentaria laciniata Muhl.	Toothwort
Dryopteris sp. Adams	Wood fern
Equisetum arvense L.	Horsetail
E. hyemale L.	Scouring rush
Erigeron philadelphicus L.	Fleabane
Erysimum repandum L.	Treacle mustard
Erythronium albidum Nutt.	White dog's tooth violet
Fragaria virginiana Duchesne	Strawberry
Galium spp.	Bedstraw
Geranium dissectum L.	Dissected geranium
G. maculatum L.	Wild geranium
Gramineae spp. L. (Two)	Grass
Lamium amplexicaule L.	Henbit
L. purpureum L.	Dead nettle
Lepidium ramosissimum Nels.	Pepper grass
Lonicera japonica Thunb.	Japanese honeysuckle
Mentha spicata L.	Spearmint
Mertensia virginica (L.) Pers.	Bluebells
Osmorhiza claytoni (Michx.) C. B. Clarke	Sweet cicely
Oxalis stricta L.	Erect wood-sorrel
Parthenocissus quinquefolia (L.) Planch.	Virginia creeper
Phlox divaricata L.	Phlox
Podophyllum pletatum L.	Mayapple
Polypodium virginianum L.	Polypody fern
Polystichum acrostichoides (Michx.) Schott	Christmas fern
Potentilla sp. L.	Cinquefoil
Ranunculus abortivus L.	Kidney leaf
R. septentrionalis Poir.	Swamp buttercup
Rhus radicans L.	Poison ivy
Ribes missouriense Nutt.	Gooseberry
Rumex acetosella L.	Sheep sorrel
Sanguinaria candensis L.	Bloodroot
Smilacina stellata (L.) Desf.	False Solomon's seal
Trillium recurvatum Beck	Trillium
Urtica urens L.	Burning nettle
Uvularia perfoliata L.	Bellwort
Veronica arvensis L.	Corn speedwell
V. peregrina L.	Purslane speedwell
Vinca minor L.	Common myrtle
Viola papilionacea Pursh	Blue violet
V. pensylvanica Michx.	Yellow violet
V. kitaibeliana var. *rafinesquii* (Greene) Fern.	Field pausy

TABLE 4.—A comparison of five locations of tree communities in Illinois showing the Relative Basal Area

Species	Numbers of Locations[1]									
	1	9	2	3	7	6	5	10	8	4
Hickory species	3	15	12	19	T[2]	17	24	17	13	14
White oak group	3	5	3	T	13	34	27	24	47	48
Red, Black oak § group §	8	5	2	4	18	41	39	23	25	14
Dogwood	3	T	T	T		1	2		T	T
Ash species	6		3	5	10	1	4		1	1
Horse chestnut						1	1			
Black cherry			1	1	T	4			T	
Red maple	5	23	1				1	9		
Sugar maple		4	26	25	36	1	1	1	5	10
Silver maple		6					1	4		
Sycamore	32	10	2	1	T					1
Elm species	8		5	4	6			T	1	3
Buckeye	1		1	T	1					T
Black walnut	6		2	4	2				3	1
Basswood	13		1		6					
Hackberry	2		2	2	5					T
Sour gum	3									
Persimmon	5									
Kentucky coffee tree	2				T					
Box elder	T	T	1							
River birch			1							
Hornbeam			T	1						T
Beech		21	21	20				10	1	1
Honey locust		1	T		T			T		
Sweet gum		T	T					T		
Tulip tree			12	9						3
Black gum			4	5						3
Sassafrass	T		T					T	1	1
Red cedar		3						2		T
Hawthorn					T					
Pawpaw					T					
Spicebark					T					
Bladdernut					T					
Hop hornbeam					T				1	
Other		7			3			10	2	
Totals	100	100	100	100	100	100	100	100	100	100

1. Location 1 Union Hill Terrace, Central Illinois
   Location 2 Lusk Creek Terrace, Southern Illinois
   Location 3 Little Lusk Creek Terrace, Southern Illinois
   Location 4 Lusk Creek Slope, Southern Illinois
   Location 5 Union Hill Slope, Central Illinois
   Location 6 Union Hill Upland, Central Illinois
   Location 7 Brownfield Woods Upland, Northern Illinois
   Location 8 Clark County Upland, Northern Illinois
   Location 9 Shawnee National Forest Terrace, Southern Illinois
   Location 10 Shawnee National Forest Upland, Southern Illinois

2. T = Trace

Results and Discussion — Comparisons

Two other general Illinois areas were compared with Union Hill communities. The data in published reports of these studies were in basal area of the trees. The relative basal area (relative dominance) was determined for all communities. The individual species data of oak, hickory, ash and elm from the published reports were grouped in the same manner as with the Union Hill data. Two upland communities were located in northern Illinois — the Brownfield Woods (Boggess and Bailey, 1964) and an oak-hickory-maple woodlot in Clark County (Ebinger and Parker, 1969). The 27 plots of the Union Hill site were grouped into three communities — terrace, slope, and upland — for the purposes of comparison. Five communities were located in southern Illinois — the Lusk and Little Lusk Creek terraces and Lusk Creek slope (Ashby, 1968) and the Shawnee National Forest terrace and upland (Giedeman and Kumler, 1970). The relative basal areas for these ten communities are presented in Table 4. Figure 3 shows the X and Y values in the ordination of these communities. The ordination is 1, 9, 7, 2, 3, 6, 5, 10, 8, and 4. The Union Hill terrace (1) is represented as one extreme and becomes reference point (a) on the X-axis with a value of O. Lusk Creek slope (4) is the second reference point (b) on this same axis, 85 units apart from a. Lusk Creek terrace (2) is reference stand c of the Y-axis with a value of O. Lusk Creek slope is reference stand d on the Y-axis with a value of 0.85.

One conclusion to be drawn from these data is that Brownfield Woods (7) an upland community in northern Illinois appears to be similar to terrace communities in southern Illinois. In the ordination this tract has values on both the X-and Y-axes close to the Lusk Creek terrace. The Union Hill terrace (1) is very dissimilar to any other community examined although plot 8 in this area is not dissimilar from Union Hill slope and upland. This is emphasized by the fact that this site is the reference point on both the X- and Y-axes (a and d). The other terrace regions Shawnee National Forest (9), Lusk Creek (2), and Little Lusk Creek (3) are closely related as shown by their locations on the X- and Y-axes.

Union Hill upland (6) and slope (5) are again shown to be very nearly alike. These communities along with the Shawnee National Forest upland (10) and Clark County upland (8) have X and Y values which cluster around the Lusk Creek slope (4) values, showing similarity in vegetational composition.

The Brownfield Woods is of mixed-mesophytic composition with hard or sugar maple as the now dominant species. Both beech and tulip tree which are characteristic of the Western Mesophytic Forest described by Braun (1950) are missing. These forests developed on uplands which were occupied by prairie grasslands from four to six hundred years ago. White oak is also characteristically absent (Boggess and Bailey, 1964). The elms were destroyed by disease between 1960 and 1962 (Kulfinski, 1970). There were only nine dominant trees or groups of trees from among the 25 species listed. This somewhat atypical upland forest of the Western Mesophytic type showed a closer relationship to Lusk Creek and Shawnee National Forest terraces than to the Clark woodlot.

The Lusk Creek terrace showed ten dominants (Ashby, 1968), consisting of sugar maple, beech, tulip tree, bitternut hickory, black gum, pignut hickory, ash species, shagbark hickory, sycamore, and American elm. Little

Lusk Creek terrace had in addition to these species red elm, black walnut, and red oak instead of shagbark hickory, sycamore, and American elm.

The Lusk Creek slope dominants were white oak, red oak, pignut hickory, black oak, sugar maple, tulip tree, red elm, black gum, chinquapin oak, and shumard oak. This community composition was the most dissimilar of the terrace communities.

Clark county woodlot had a total of 23 tree species (Ebinger and Parker, 1969). The dry, relatively flat uplands were dominated by white oak, with black oak and shagbark hickory the most common associates. The steep, north-facing slopes were dominated by sugar maple, red oak, and to a lesser degree, bitternut hickory, beech, and ironwood. The remainder of the woods consisted of gentle to relatively-steep slopes and a lowland area in which white oak dominated, associated with black and red oaks, and shagbark hickory.

The Shawnee National Forest terrace contained an association mainly of beech, red maple, black willow, cottonwood, and sycamore. The oaks and hickories were also found here, but these were not the dominants. Red cedar was found throughout both terrace and upland, although it was found in greater abundance in the latter community. The highest concentration of hickories and oaks were found in the upland. Beech persisted into the lower elevations of the upland as well as elm species, sassafrass, tulip tree, and the maples. A pine plantation is also a part of the upland sites.

From this comparison of various forest communities in different parts of Illinois and from an inspection of the species list (Table 2) one sees that the number of tree species increases as one moves southward in Illinois. The northern communities had an average of 26 tree species, Union Hill representing central Illinois had 32, and the southern communities of Lusk Creek and Shawnee National Forest had an average of 42 species.

This comparison of these communities with its attendant ordination is a valid method for the study of different communities within a floristic region. The ordination technique enables one to examine the distributional relationships among species as well as communities. But whether the vegetation is merely described and classified rather than studied as a continuum, there is an urgent need for completion of such studies of natural areas before they are completely destroyed by man's activities.

Acknowledgements

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THE VEGETATION OF AN ABANDONED ROAD AFTER A HALF CENTURY OF DEVELOPMENT

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ABSTRACT.—After 85 years as a country road, a portion of a highway in Ogle County was abandoned in 1922, leaving it to successional development. Changing from an open road with only a few small fencerow trees, the roadway is now a pathway covered with a canopy of trees. An analysis of the trees in 420 feet of roadway reveals an *Acer negundo-Juglans nigra* association comprising 59.8% of the total tree population. The remainder of the trees include ten species, with *Celtis occidentalis* the most abundant of the younger trees. The thirteen species of shrubs and vines present are nearly all commonly found in open woods or along unmowed roadways. About 50 species of herbs comprise the dense ground cover. With one exception, all are common plants of northern Illinois. They represent several variations in woodland habitats. Such an abandoned area as this becomes a refuge for plants and animals and offers opportunities for successional study as well as a place for the enjoyment of natural phenomena.

Roadways are not usually of ecological interest except when their construction destroys natural habitats or covers valuable agricultural land. After modern highways are built, their roadsides are regularly mowed and sprayed, so that few species of plants are to be found there.

In this study we consider the role of ecological succession in vegetating an old roadway after it had been used for about 85 years and then abandoned in favor of a new route. This is an uncommon occurrence in northern Illinois.

Early in 1837 a petition was presented in the Court of Ogle County for permission to establish a road which would begin at Dixon, pass through Grand Detour and Oregon, and continue to Byron. Its route from Grand Detour to Byron was on the west side of the Rock River (Boss, 1859). The petition was granted and the road was laid out shortly afterwards. This road became the principal highway up the Rock River valley. It apparently was surfaced with gravel until it was paved with concrete about 1922. It then became Illinois Highway 2.

At the site of this study the highway was rerouted about 100 yards to the east, leaving a section of the old road abandoned. This strip became a part of the adjacent farm property under private ownership. For many years it was used as a pathway for foot travel and the movement of farm vehicles. During the past decade the center of the road has been kept open as a footpath by occasional mowing.

The site is located near the center of section 33 of Rockvale Township

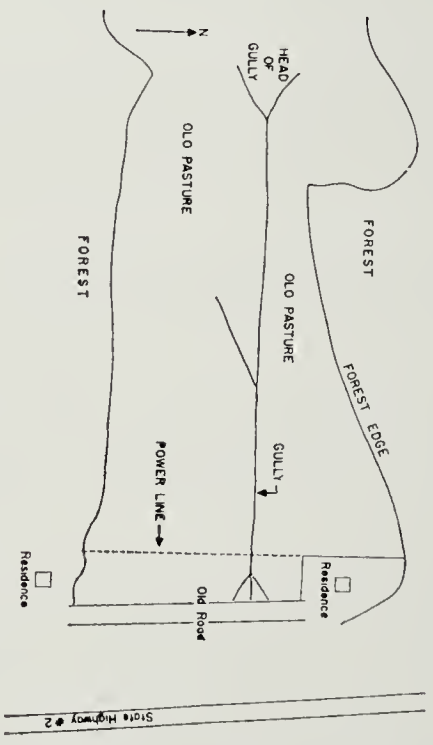

FIGURE 1.—The study area at The Stronghold, Oregon, Illinois.

FIGURE 2.—The south entrance to the abandoned roadway at The Stronghold. The beginning of the study area is indicated by the line across the upper part of the mowed area. The blue spruce at the left is a part of the landscape plantings of the adjacent homesite.

(T24N., R10E.), Ogle County, Illinois. Figure 1 shows the relationship of the study site to adjacent areas. It is a part of the property known as The Stronghold, now owned by the Presbyterian Camping Association of Northern Illinois. The old right-of-way appears to have been 56 feet wide. Exact boundaries are difficult to determine because old fences were removed long ago. The portion studied, located between two homesites, is 420 feet long. It covers approximately 23,520 square feet, .54 acre.

A photograph published in 1904 (Newton, 1904) shows the road in use by horsedrawn vehicles. Pasture and a cultivated field were on the west and east sides respectively. Only a few clumps of small trees were present along the fences separating road and fields at that time.

We can assume that there was unrestricted growth of vegetation along the road after abandonment in 1922. A United States Department of Agriculture aerial photograph of 1939 showed the center of the road as an open and apparently used lane. The canopy of fencerow trees had not yet closed over the center. Small groups of trees and individuals were quite distinct along the fences on both sides. A 1951 aerial photo showed the fencerow trees as a solid line on each side of the central lane, which was partially covered by the overhang of trees. In a later photo of 1964, the central lane was almost totally obscured by the tree canopy. Figure 2 indicates the appearance of the road today as one enters the central pathway from the south end.

PROCEDURE

A complete survey of the woody vegetation was made in October of 1970. Measurement and identification of all the trees on the 420 feet of roadway were carried out separately on each side of the central pathway in successive plots 10 feet in width. Because of the small size of the area, it was studied in entirety rather than by sampling techniques. All trees were identified, measured, and recorded (Table 1). Only the presence of shrubs and vines was noted. (Appendix 1). The herbaceous plants were identified in several reconnaissance surveys in the spring and autumn of 1970 and 1971. Their listing in Appendix 2 is not intended to be a complete or final compilation of the flora of the plot. The infrequency of visits to the site precluded a thorough and complete analysis of herbs. Some identifications have been indicated as incomplete or tentative. Future visits are likely to reveal a gradual change in the herbaceous ground cover.

DISCUSSION

The tree populations of the adjacent Strong field and gully (see Figure 1 for location) have been reported previously (Bullington, 1970, 1971). There is greater diversity of

TABLE 1.—Analysis of trees in 420 feet of roadway.

Size categories	Under 1 inch dbh		1-6 inches dbh		6-12 inches dbh		Over 12 inches dbh		Totals			
Species	West side	East side	West side	East side	West side	East side	West side	East side	West side	East side	Com-bined	%
Acer negundo L.	34	21	16	27	15	11		4	65	63	128	34.5
Carya ovata K. Kock							2		2		2	0.5
Celtis occidentalis L.	8	16	40	18					48	34	82	22.1
Fraxinus sp.			1						1		1	0.3
Juglans nigra L.	2	4	22	48	2	5	9	2	35	59	93	25.3
Pyrus ioensis Bailey			1						1		1	0.3
Morus sp.			1						1		1	0.3
Prunus serotina Ehrh.	1	8	3	6			1		5	14	19	5.1
Prunus virginiana L.		2		2						4	4	1.1
Ulmus americana L.	1		13	4	1				15	4	19	5.1
Ulmus pumila L.	1								1		1	0.3
Ulmus rubra Muhl.		5	6	8					6	13	19	5.1
Totals	47	56	103	113	18	16	12	6	180	191	371	100.0

species in each of these locations than in the roadway area. Twenty-six species of trees were reported from the field and 22 from the gully, compared with only 12 in the roadway. The small number of tree species in the roadway is due to the smaller area and to less diversity of habitat.

Acer negundo was the principal pioneer of the old field and it is also the most abundant tree of the roadway with 34.5% of the total tree population (Table 1). Thirty of the 128 box elders are over six inches in diameter at breast height. Four of these are over 12 inches dbh. Fifty-five of the box elders are under one inch. However, most of these are basal sprouts from mature trees and do not represent new invasion. Undoubtedly, box elder was one of the two most abundant trees of the first invaders, but experience with the rapid demise of this species in the nearby gully would indicate that it will decline in importance in the roadway. Some of the older trees are now deteriorating, and the closed canopy will prevent new reproduction.

The other early invader of importance was *Juglans nigra* which now has 94 individual trees comprising 25.3% of the total. Eleven of the walnuts are over 12 inches dbh and seven more are between six and 12. The largest specimen is 31 inches dbh and is a handsome open-grown tree that must have started its growth early in the century. However, it cannot be seen in the early photograph (Newton, 1904). The adundant seed source from nearby forests, as well as from the older invaders, has resulted in considerable reproduction of walnuts, with 76 trees under six inches dbh present. The present roadside forest is essentially an association of walnut and box elder.

Few other trees are represented by specimens over six inches dbh. There are two large *Carya ovata* trees, with no younger ones. *Prunus serotina,* usually a common fencerow tree, is represented by only one large tree and 18 others under six inches dbh. There is only one other tree over six inches, an *Ulmus americana.* This species has 18 smaller trees. Because of the prevalence of the Dutch elm disease in adjacent areas, where it has decimated one half of this species in the gully (Bullington, 1971), the survival of the present living American elms is in doubt. Nineteen small *Ulmus rubra* are present.

The most significant development of young trees in the study area is the 82 *Celtis occidentalis,* comprising 22.1% of the tree population. Its third place rank in the roadway corresponds with a similar rank among the trees of the Strong field in 1969 (Bullington, 1971). It is less abundant in the gully and forest sites nearby. It seems that this species is introduced into a successional area after pioneer trees have been established. No doubt its seeds are brought in by tree-inhabiting birds.

Single specimens of two species of small trees, not previously reported from old field or gully, have been tentatively identified as *Morus rubra,* the red mulberry, and *Fraxinus pennsylvanica subintegerrima,* the green ash. Fruits of neither have been found for verification of identity. Both species are present elsewhere in the vicinity.

In the tally of trees, separate records were kept for the east and west sides of the roadway. A total of 191 was found on the east side and 180 on the west (Table 1). *Acer negundo* was equally abundant on each side. Somewhat more abundant on the east than on the west were *Juglans, Prunus,* and *Ulmus rubra.* On the west *Celtis* and *U. americana* were more common than on the east. No importance is attached to these appar-

ently chance differences in distribution.

Some species of trees are notable because of their absence. Prominent in various places in adjacent forest, old field, or gully, but totally absent from the roadway are species of *Quercus, Juniperus, Populus, Crataegus, Ptelea, Pyrus,* and *Prunus americana.* Since all except *Quercus* are pioneer species in secondary succession, they are unlikely to become more than chance invaders of the already occupied area of the roadway. *Quercus* species may enter with future successional development, especially *Q. velutina,* which is a prominent component of adjacent old field and forest areas, although the closed canopy may inhibit oak development.

Most of the thirteen species of shrubs and vines listed in Appendix I are plants commonly found along fencerows of unmowed country roadways. Three, *Corylus americana, Rubus occidentalis,* and *Rhus radicans,* are frequent components of such habitats. The fruits of eight or nine of the thirteen are usually eaten by birds and then may be deposited along fences. Several species in the roadway are common inhabitants of open woods and so would be expected to be found with the pioneer trees of the developing woodland. These include *Parthenocissus quinquefolia, Ribes missouriense, Smilax tamnoides, Sambucus canadensis,* and *Vitis riparia.* Two are chance invaders from horticultural plantings, namely, *Lonicera tatarica* and *Philadelphus coronarius.* There is a single mature specimen of each.

All of the species of herbaceous plants identified to date and listed in Appendix II are common plants of northern Illinois, present in most of the northeastern counties of the state (Swink, 1969), with one exception noted below. Although Ogle County was not included in Swink's study, it is adjacent to DeKalb County which is, and the flora would be expected to be similar. Continuing study will no doubt add new species to those discovered so far in the roadway. Some of the less abundant ones may disappear.

The herbs present represent several variations of natural habitat. A few are survivors of the open roadside days, such as *Poa pratensis, Pastinaca sativa,* and *Solidago* sp. The mowed central strip is similar to a degraded lawn, with *Taraxacum officinale* and *Cerastium vulgatum* being widely distributed.

Introduced weeds of disturbed woodlands and waste areas are common. Some of the more typical ones are *Arctium minus, Leonurus cardiaca,* and *Polygonum convolvulus.* Other herbs typical of such habitats are *Eupatorium rugosum, Geranium maculatum, Phryma leptostachya,* and *Ranunculus abortivus.*

The tree components of the roadway have developed sufficiently to make the habitat suitable for herbs common to northern Illinois deciduous forests. Of common occurrence are *Elymus villosus, Galium aparine, G. circaezans, Sanicula gregaria, Viola papilionacea* and *V. pennsylvanica.* Still uncommon, but serving to indicate the development of forest characteristics are *Eupatorium purpureum* and *Podophyllum peltatum.*

Near the north end of the roadway, sediments from the outlet of an old gully have been deposited. (See Bullington, 1971, for a report on succession in this gully). Active erosion has ceased, but the drainage from the gully still supplies water to this portion of the site, producing conditions similar to a floodplain. Here are found plants common to floodplains and moist woods, including *Campanula americana, Dioscorea villosa, Impatiens pallida, Laportea canadensis,* and *Rudbeckia laciniata.*

In one wet area, a colony of *Mertensia virginica* has been thriving for many years.

In this location near landscaped homesites and gardens, one would expect to find some introduced cultigens that have spread from their original setting. Two such shrubs, *Lonicera* and *Philadelphus,* were mentioned above. A recent discovery was a few specimens of *Chelidonium majus,* reported by Fernald (1950) as naturalized from Europe and by Swink (1969) as an occasional escapee from flower gardens. According to Fell (1955) it is rare in northern Illinois. *Chelidonium majus* is the only unusual species found in the roadway so far.

Summary and Conclusions

There is considerable diversity of flora in this abandoned half-acre of old roadway that has undergone secondary successional development for half a century. Twelve species of trees, thirteen of shrubs and vines, and nearly 50 of herbaceous plants have been identified. The present dominant trees are those that invaded the roadside first, *Acer negundo* and *Juglans nigra.* The only other tree with considerable numbers is *Celtis occidentalis,* a secondary invader represented by numerous small trees. The shrubs and vines are mostly fruit-bearing species commonly introduced by birds.

The development of the tree canopy has made possible the invasion of a dense ground cover of numerous species of herbs typical of woodlands. Some weedy species common to roadsides and fencerows are still present.

This study shows that a small abandoned area of little economic value can serve useful scientific purposes. Its successional development offers a clue to the expectations of recovery of badly used or deteriorated plots of ground. It is evident that such an area can be revegetated within a few decades with typical plants. As a refuge for a large variety of organisms, it provides a useful site for successional and taxonomic studies.

Furthermore, the plot has aesthetic value as a place for the enjoyment of nature, a mini-park where the recreational values of being close to nature can be pursued.

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Appendix I.—Shrubs and Vines of Roadway

Key: r = rare, one or very few specimens found
a = abundant, widely distributed
* = not previously found elsewhere in Strong Field
? = identification tentative

r * *Celastrus scandens* L. — climbing bittersweet

r * *Corylus americana* Walt. — American hazelnut

r * *Hamamelis virginiana* L. — witch hazel

r *Lonicera prolifera* (Kirchn.) Rehd. — grape honeysuckle

r * *Lonicera tatarica* L. — Tatarian honeysuckle
Parthenocissus quinquefolia Planch. — Virginia creeper
r * *Philadelphus coronarius* L. (?) — mock orange
Rhus radicans L. — poison ivy
Ribes missouriense Nutt. — Missouri gooseberry
a *Rubus occidentalis* L. — black raspberry
a *Sambucus canadensis* L. — common elderberry
Smilax tamnoides L. *hispida* (Muhl.) Fern. — bristly greenbrier
Vitis riparia Michx. — riverbank grape

Appendix II.—Herbaceous Plants of Roadway

Key: r = rare, one or very few specimens found
a = abundant, widely distributed
* = not previously found in Strong Field
? = identification tentative

r * *Agastache nepetoides* (L.) Ktze. — yellow giant-hyssop
Agrimonia gryposepala Wallr. — tall agrimony
Arctium minus (Hill) Bernh. — common burdock
* *Aster pilosus* Willd. — hairy aster
* *Aster sagittifolius* Wedemeyer — arrow-leaved aster
Brassica nigra (L.) Koch — black mustard
Carex sp. — sedge
Campanula americana L. — tall bellflower
* *Cerastium vulgatum* L. — mouse-ear chickweed
r * *Chelidonium majus* L. — celandine
Cirsium altissimum (L.) Spreng. (?) — tall thistle
* *Cryptotaenia canadensis* (L.) DC. — honewort
Desmodium glutinosum (Muhl.) Wood — pointed tick-trefoil
r * *Dioscorea villosa* L. — wild yam
* *Elymus villosus* Muhl. — wild rye
r *Eupatorium purpureum* L. — Joe-pye-weed
Eupatorium rugosum Houtt. — white snakeroot
a *Galium aparine* L. — bedstraw
Galium circaezans Michx. — wild licorice
Geranium maculatum L. — wild cranesbill
Geum canadense Jacq. — white avens
* *Hackelia virginiana* (L.) I.M. Johnston — beggar's lice
r *Impatiens pallida* Nutt. — pale touch-me-not
Lactuca floridana (L.) Gaerntn. (?) — blue lettuce
Laportea canadensis (L.) Wedd. — wood nettle
r * *Leonurus cardiaca* L. — motherwort
Mertensia virginica (L.) Pers. — Virginia bluebells
Osmorhiza Claytoni (Michx.) C. B. Clarke — hairy sweet cicely
* *Oenothera* sp. — evening primrose
Pastinaca sativa L. — parsnip
* *Phryma leptostachya* L. — lopseed
a *Poa pratensis* L. — Kentucky bluegrass
r *Podophyllum peltatum* L. — mayapple
r * *Polygonatum canaliculatum* (Muhl.) Pursh — smooth Solomon's seal
* *Polygonum convolvulus* L. — black bindweed
Ranunculus abortivus L. — kidneyleaf buttercup
Rudbeckia laciniata L. — golden-glow
Sanicula gregaria Bickn. — black snakeroot
r *Scrophularia marilandica* L. — late figwort
r *Senecio aureus* L. (?) — golden ragwort
r *Smilacina stellata* (L.) Desf. — false Solomon's seal
Solidago sp. — goldenrod
r * *Stachys palustris* L. *homotricha* Fern. (?) — woundwort
Taraxacum officinale Weber — common dandelion
r * *Thalictrum revolutum* D.C. — purple meadow rue
r * *Tovara virginiana* (L.) Raf. — jumpseed
r * *Urtica gracilis* Ait. — tall nettle
Viola papilionacea Pursh — common blue violet
Viola pennsylvanica Michx. — smooth yellow violet

HELMINTHS OF THREE SYMPATRIC SPECIES OF CAVE-DWELLING SALAMANDERS IN SOUTHERN ILLINOIS

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ABSTRACT.—Samples of three sympatric species of salamanders comprising 322 zigzag salamanders, *Plethodon dorsalis*, 41 slimy salamanders, *P. glutinosus*, and 17 cave salamanders, *Eurycea lucifuga*, were collected in a cave in southern Illinois and examined for helminths. The parasites recovered included *Brachycoelium* sp., *Cosmoceroides dukae*, *Oxysomatium* sp. and *Physaloptera* sp. The occurrence of *Brachycoelium* sp. and *C. dukae* in *P. dorsalis* constitutes new host records. Checklists of these helminths from salamanders in the contiguous United States are included.

While the literature on helminth parasites of amphibians in the contiguous United States is extensive, the majority of reports are confined primarily to the parasites of anurans. With the exception of comprehensive surveys conducted by Harwood (1932), Mann (1932), Rankin (1937, 1945) and Fischthal 1955a), little is known of salamander helminths. The majority of papers are restricted either to descriptions of new species or lists of helminths in a few salamanders made in connection with more extensive studies on other amphibians and reptiles.

Although the biology and habitats of several species of salamanders in southern Illinois have been investigated, little information on their helminth fauna is available. A previous survey of parasites in salamanders of this region was undertaken by Landewe (1963). However, his information has not been published. An account of the intestinal helminths of three sympatric species, *Plethodon dorsalis*, *P. glutinosus* and *Eurycea lucifuga*, is presented in this paper.

All salamanders were collected in Equality Cave, five miles southwest of Equality, Saline County, Illinois between November, 1963 and September, 1967. Although collections were made systematically, by month, for studies of salamander reproductive cycles, the number of specimens of *P. glutinosus* and *E. lucifuga* was regrettably low in comparison to *P. dorsalis*, resulting in insufficient data for analysis of seasonal abundance of helminths. These salamanders are not limited to caves, but *E. lucifuga* is basically an inhabitant of cave entrance ways, and the other two species, though inhabitants of forest floors, commonly use caves as brooding sites, and as retreats from drying woodlands.

None of the mature parasites examined are considered as new, but we report new host records and extend the known geographical range of several species.

MATERIALS AND METHODS

As the primary purpose for collecting these salamanders involved studies of reproductive cycles, the 380 salamanders including 322 *P. dorsalis*, 41 *P. glutinosus* and 17 *E. lucifuga* were fixed in 10% formalin and transfered to 70% ethanol. Since the entire digestive tract was placed in alcohol, few protozoans were found in a condition that would warrant accurate identification. Trematodes were stained with Schneider's acetocarmine or Delafield's hematoxylin, cleared in beechwood creosote and mounted in Permount. Nematodes

TABLE 1.—Intestinal helminths of 380 salamanders collected in Equality Cave, Saline Co., Illinois.

Species of parasite	Species of salamander	Number examined	Number infected	Per cent infected
Brachycoelium sp.	*Plethodon dorsalis*	322	34	10.6
	Eurycea lucifuga	17	1	5.9
	Plethodon glutinosus	41	10	24.4
Cosmocercoides dukae	*Plethodon dorsalis*	322	13	4.0
	Eurycea lucifuga	17	3	0.9
Oxysomatium sp.	*Eurycea lucifuga*	17	1	5.9
Physaloptera sp.	*Plethodon dorsalis*	322	1	0.3

were cleared in glycerine and studied in temporary mounts. The anterior ends of some specimens were removed and mounted in glycerine-jelly for *en face* studies.

RESULTS AND DISCUSSION

Two species of nematodes and one trematode were recovered from 46 of 322 specimens of *P. dorsalis* and 4 of 17 of *E. lucifuga*. One species of trematode was found in 10 of 41 specimens of *P. glutinosus* (Table 1). The absence of tapeworms and acanthocephalans in *Plethodon,* which has a completely terrestrial life cycle, is not surprising. The occurrence of cestodes in salamanders appears to be essentially correlated with an aquatic environment. According to Rankin (1937) many larval salamanders become accidentally infested by ingesting infected copepods but the cestodes mature in few salamander species. Their absence in *E. lucifuga,* which does have an aquatic larval stage, may be an artifact of small sample size.

TREMATODA

Brachycoelium sp.

Species of *Brachycoelium* are the most common flukes encountered in salamanders and in the present study *Brachycoelium* sp. was the only fluke collected. It was recovered from the small intestine of 45 (11.8%) of 380 salamanders examined. All three species of salamanders were found infected with this parasite. It occurred as a single infection in 41 salamanders and as a double infection with *Cosmocercoides dukae* in 3 *P. dorsalis* and 1 *E. lucifuga.* In *E. lucifuga,* only 5.9% of the hosts examined were infected and the average number of flukes per host was 4.3, while the terrestrial species, *P. dorsalis* and *P. glutinosus* were 10.6 and 24.4% infected, respectively. In *Plethodon,* the number of flukes per host ranged from 2 to 30. Crowding appeared to have a direct effect on the size of the flukes substantiating the conclusions of Rankin (1938) that heavy infections of *B. salamandrae* tend to produce many small flukes, whereas light infections are usually made up of larger specimens.

Landewe (1963) found *B. salamandrae* in *Ambystoma maculatum, A. opacum, A. talpoideum, Eurycea longicauda, E. lucifuga* and *Plethodon glutinosus* in Illinois. To our knowledge *P. dorsalis* constitutes a new host record for *Brachycoelium* sp.

Considerable differences of opinion exist in regard to the number of species in the genus *Brachycoelium.* Those reported exhibit wide variability in regard to size, shape and position of specific characters. Stafford

(1900) described *Distomum hospitale* from *Notophthalmus viridescens* in Canada, the first species of *Brachycoelium* reported from North America, and in 1903 assigned it to the proper genus. Since Stafford's report several species have been added as follows: *B. obesum* Nicoll, 1914; *B. trituri* Holl, 1928a; *B. storeriae* Harwood, 1932; *B, meridionalis* Harwood, 1932; *B. daviesi* Harwood, 1932 and *B. lynchi* Ingles, 1936. Byrd (1937) described five new species: *B. mesorchium, B. georgianium, B. ovale, B. dorsale,* and *B. louisianae.*

Rankin (1937) reduced *B. obesum, B. daviesi, B. meridionalis, B. storeriae* and *B. trituri* to synonymy with *B. hospitale.* In 1938, the same author presented a classic study on the variability of morphological characters in *Brachycoelium* in an attempt to evaluate their reliability for separation of species. He pointed out the error of many previous workers in describing new species on the basis of data obtained by examination of a few specimens from an individual host and demonstrated that while certain features may seem to be divergent enough to justify describing a new species they can only be fully evaluated when observed on many individuals from various hosts. Rankin concluded that the genus *Brachycoelium* is represented in North America by a single species, *B. salamandrae.* Manter (1938) also indicated the taxonomic difficulties existent in this genus and the doubtful validity of many characters considered to be diagnostic of species.

Parker (1941) and Cheng (1958), however, opposed any attempt to synonymize the various North American species of *Brachycoelium* and recognized 7 and 10 distinct species of *Brachycoelium,* respectively.

Cheng and Chase (1961) and Couch (1966), respectively, added *B. stablefordi* and *B. ambystomae* to the genus.

Rankin (1938), Parker (1941) and Cheng (1958) unanimously agreed that the problem of species evaluation would have to be resolved, eventually, by life history studies.

To our knowledge, only two life history studies have been reported, those of *B. obesum* and *B. mesorchium* by Cheng (1960) and Jordan (1962), respectively. Both species utilize terrestrial snails as intermediate hosts. The study on *B. obesum* seems questionable since Cheng failed to explain how he determined the intermediate hosts were parasite-free prior to challenge. Jordan concluded that more than one species of *Brachycoelium* must be recognized for the following reasons: (1) *Brachycoelium* eggs from different definitive hosts would not develop in the same intermediate host, (2) similar snail hosts failed to become infected when exposed to eggs from similar definitive hosts from a different region, and (3) *B. mesorchium* failed to develop in some of the proven definitive hosts of *Brachycoelium.*

We have experienced difficulty in assigning specimens to described species because of variation in so-called specifically valid characters and for this reason, all specimens of *Brachycoelium* reported in this investigation are referred to as *Brachycoelium* sp..

The following list represents the geographical distribution of *Brachycoelium* reported from various salamander hosts in the contiguous United States. In view of the taxonomic problem of species recognition, scientific names of these flukes are given as originally reported with the exception *B. salamandrae* (=B. *hospitale*).

Ambystoma jeffersonianum — B. salamandrae, Massachusetts (Rankin, 1945).

Ambystoma macrodactylum — *B. salamandrae*, Idaho (Waitz, 1961).
Ambystoma maculatum — *B. salamandrae*, N. Carolina (Rankin, 1937, 1938), Massachusetts (Rankin, 1945), Illinois (Landewe, 1963).
Ambystoma opacum — *B. ambystomae*, Florida (Couch, 1966); *B. dorsale*, Louisiana (Byrd, 1937); *B. louisianae*, Louisiana (Byrd, 1937); *B. salamandrae*, N. Carolina (Mann, 1932; Rankin, 1937, 1938); Illinois (Landewe, 1963); *B. storeriae*, Tennessee (Parker, 1941).
Ambystoma talpoideum — *B. salamandrae*, Illinois (Landewe, 1963).
Ambystoma texanum — *B. daviesi*, Texas (Harwood, 1932); *B. salamandrae*, Texas (Harwood, 1932).
Amphiuma tridactylum — *B. salamandrae*, Louisiana (Bennett and Humes, 1938).
Desmognathus fuscus — *B. meridionalis*, Georgia (Parker, 1941); *B. mesorchium*, Georgia (Byrd, 1937; Parker, 1941; Denton, 1962), Virginia (Cheng, 1958); *B.obesum*, Georgia (Byrd, 1937; Parker, 1941); *B. ovale*, Georgia (Parker, 1941); *B. salamandrae*, N. Carolina (Mann, 1932; Rankin, 1937), Massachusetts (Rankin, 1945), Ohio (Odlaug, 1954), New York (Fischthal, 1955a), Pennsylvania (Fischthal, 1955b), Tennessee (Rankin, 1938); *B. trituri*, Georgia (Byrd, 1937).
Desmognathus ochrophaeus carolinensis — *B. salamandrae*, N. Carolina (Rankin, 1937).
Desmognathus monticola — *B. elongatum*, Virginia (Cheng, 1958); *B. salamandrae*, N. Carolina (Rankin, 1937).
Desmognathus quadramaculatus — *B. elongatum*, Virginia (Cheng, 1958); *B. salamandrae*, N. Carolina (Rankin, 1937).
Eurycea b. bislineata — *B. salamandrae*, Massachusetts (Rankin, 1945), New York (Fischthal, 1955a), Pennsylvania (Fischthal, 1955b).
Eurycea b. cirrigera — *B. obesum*, Georgia (Parker, 1941); *B. salamandrae*, N. Carolina (Mann, 1932; Rankin, 1937).
Eurycea b. wilderae — *B. salamandrae*, N. Carolina (Rankin, 1937).
Eurycea longicauda — *B. salamandrae*, Illinois (Landewe, 1963).
Eurycea longicauda guttolineata — *B. salamandrae*, N. Carolina (Rankin, 1937).
Eurycea lucifuga — *B. salamandrae*, Illinois (Landewe, 1963).
Gyrinophilus p. porphyriticus — *B. salamandrae*, New York (Fischthal, 1955a).
Hemidactylium scutatum — *B. salamandrae*, Michigan (Rankin, 1938).
Notophthalmus meridionalis — *B. daviesi*, Texas (Harwood, 1932); *B. meridionalis*, Texas (Harwood, 1932).
Notophthalmus viridescens — *B. salamandrae*, Michigan (Cort, 1915, 1919), N. Carolina (Mann, 1932; Rankin, 1937, 1938; Russell, 1951), New York (Rankin, 1938; Fischthal, 1955a), Virginia (Russell, 1951), Massachusetts (Rankin, 1938, 1945), Pennsylvania (Kelley, 1934); *B. trituri*, N. Carolina (Holl, 1928a, 1932), Massachusetts (Kelley, 1934), Ohio (Kelley, 1934), Virginia (Cheng, 1958).
Phaeognathus hubrichti — *B. salamandrae*, Alabama (Brandon, 1965).
Plethodon cinereus — *B. louisianae*, Virginia (Cheng, 1958); *B. obesum*, Virginia (Cheng, 1958, 1960), Pennsylvania (Cheng, 1960); *B. salamandrae*, N. Carolina (Rankin, 1937, 1938), Massachusetts (Rankin, 1945), New York (Fischthal, 1955a), Pennsylvania (Fischthal, 1955b), Virginia (Cheng, 1958); *B. storeriae*, Virginia (Cheng, 1958), Pennsylvania (Cheng and Chase, 1961).
Plethodon glutinosus — *B. elongatum*, Virginia (Cheng, 1958); *B. meridionalis*, Georgia (Parker, 1941); *B. obesum*, S. Carolina (Byrd, 1937), Georgia (Parker, 1941), Pennsylvania (Cheng, 1960), Virginia (Cheng 1958, 1960); *B. ovale*, Georgia (Parker, 1941); *B. salamandrae*, N. Carolina (Mann, 1932; Rankin, 1937, 1938), Louisiana (Byrd, 1937), Tennessee (Rankin, 1938), New York (Fischthal, 1955a), Virginia (Cheng, 1958), Illinois (Landewe, 1963); *B. storeriae*, Pennsylvania (Cheng and Chase, 1961).
Plethodon j. jordani — *B. salamandrae*, N. Carolina (Rankin, 1938).
Plethodon j. metcalfi — *B. salamandrae*, N. Carolina (Rankin, 1937, 1938).
Plethodon yonahlossee — *B. salamandrae*, N. Carolina (Rankin, 1937).
Pseudotriton ruber — *B. salamandrae*, N. Carolina (Rankin, 1937, 1938); *B. storeriae*, Georgia (Parker, 1941).
Taricha granulosa — *B. salamandrae*, Oregon (Lehmann, 1954).

NEMATODA

Cosmocercoides dukae (Holl, 1928) Wilkie, 1930

This species was the most common nematode encountered. It was found in the large intestine of 16 (4.2%) of 380 salamanders examined. Infections varied from 1 to 15 specimens per host with an average of 2.4. It

occurred as a single infection in 12 salamanders and as a double infection with *Brachycoelium* sp. in 3 *Plethodon dorsalis* and 1 *Eurycea lucifuga.* This parasite has been recorded from many terrestrial and aquatic amphibians and reptiles in the United States and Canada. This is the first report of this species from *P. dorsalis* and the second from *E. lucifuga.* Landewe (1963) found this nematode in several salamanders in southern Illinois, including *Ambystoma maculatum, A. opacum, A. talpoideum, A. texanum, Eurycea lucifuga, Plethodon cinereus* (because of the collection locality, these must be *P. dorsalis)* and *P. glutinosus.*

Several authors have reported life history studies of this parasite. Anderson (1960) described the development and transmission of nematodes of terrestrial molluscs which he tentatively identified as *Cosmocercoides dukae.* Anderson (1960) and Ogren (1953) demonstrated that third-stage larvae enter the respiratory pore of snails and develop in the mantle cavity. In addition, Anderson (1960) described transovarial infection in snails. McGraw (1968) showed that snails can also become infected by ingesting contaminated amphibian feces. Anderson (1960) also showed that worms of all stages from molluscs fed to amphibians were passed at intervals in the feces and he found no evidence that this species could establish itself in amphibians. He concluded that the ability of all stages to survive indefinitely in the external environment and to pass unharmed through the gut of amphibians must be important factors in the dissemination of *C. dukae.*

The following list shows the geographical distribution of *C. dukae* reported from salamanders in the contiguous United States.

Ambystoma maculatum — Illinois (Landewe, 1963).

Ambystoma opacum — N. Carolina (Mann, 1932; Rankin, 1937), U.S.A. Walton, 1933), Ohio (McGraw, 1968), Illinois (Landewe, 1963).

Ambystoma talpoideum — Texas (Harwood, 1932; Ingles, 1936), Florida (Walton, 1938), Illinois (Landewe, 1963).

Ambystoma texanum — Texas (Harwood, 1932), U.S.A. (Walton, 1933), Illinois (Landewe, 1963).

Desmognathus fuscus — N. Carolina (Rankin, 1937), Ohio (Odlaug, 1954; McGraw, 1968), Pennsylvania (Fischthal, 1955a).

Eurycea bislineata — Ohio (McGraw 1968).

Eurycea lucifuga — Illinois (Landewe, 1963).

Notophthalmus meridionalis — Texas (Harwood, 1930; Walton, 1933).

Notophthalmus viridescens — N. Carolina (Holl, 1928b, 1932; Harwood, 1932; Rankin, 1937), Massachusetts (Rankin, 1945), New York (Fischthal, 1955a), Pennsylvania (Fischthal, 1955b), U.S.A. (Walton, 1933).

Plethodon cinereus — N. Carolina (Rankin, 1937), Massachusetts (Rankin, 1945), Illinois (Landewe, 1963) (actually *P. dorsalis).*

Plethodon glutinosus — N. Carolina (Rankin, 1937), Illinois (Landewe, 1963), Ohio (McGraw, 1968).

Plethodon longicrus — N. Carolina (McGraw, 1968).

Taricha granulosa — Oregon (Lehmann, 1954).

Taricha torosa — California (Harwood, 1932; Ingles, 1936; Lehmann, 1954), Florida (Walton, 1938).

Oxysomatium sp.

A single male specimen was collected from the large intestine of a *Eurycea lucifuga.* Unfortunately, the worm was in poor condition, thus precluding specific identification. The characters of the described species of *Oxysomatium* and *Aplectana* are so intermingled that it is difficult to determine with certainty the genus in which a species should be placed. We agree with the conclusions of Fotedar (1960) that *Aplectana* should fall as a synonym of *Oxysomatium. Oxysomatium* sp. has also been fould in *Plethodon cinereus* (actually *P. dorsalis)* in Illinois (Landewe, 1963). Mann (1932) reported *Oxy-*

somatium sp. from *Ambystoma opacum, Plethodon glutinosus* and *Notophthalmus viridescens* in North Carolina. Fischthal (1955a) recovered *O. americana* from *Eurycea b. bislineata* and *Desmognathus fuscus* and *O. longicaudata* from *P. glutinosus* and *Gyrinophilus p. porphyriticus* in south-central New York. *Pseudotriton r. ruber* was listed by Walton (1933) as a host of *O. brevicaudata* but the locality was not given.

Physaloptera sp.

Three unidentified larvae of the genus *Physaloptera* were recovered from the stomach of a single *Plethodon dorsalis*. To our knowledge no specimens of *Physaloptera* found in salamanders in the United States have been identified to species. *Physaloptera* larvae have been reported from salamander hosts as follows: *Ambystoma opacum* — N. Carolina (Mann, 1932); *Desmognathus fuscus* — N. Carolina (Mann, 1932; Rankin, 1937), Georgia (Reiber *et. al.*, 1940); *Notophthalmus viridescens* — Massachusetts (Rankin, 1945); *Plethodon glutinosus* — N. Carolina (Mann, 1932; Walton, 1935), Georgia (Reiber *et. al.*, 1940); and *Pseudotriton montanus montanus* — N. Carolina (Rankin, 1937).

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CHANGING THE PERIOD OF THE CLOCK OF THE KANGAROO RAT, *DIPODOMYS MERRIAMI*, BY LIGHT PERTURBATIONS

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ABSTRACT.—Eleven Kangaroo Rats were maintained under continuous dim illumination and nearly constant temperature, 20°C±1°C, for eight months. Their persistent locomotor activity was monitored by an event recorder. Shifts in time of activity onset in response to hour-long light perturbations given at 4- to 7-day intervals randomly distributed over a 24-hour period were investigated. It was noted that at certain critical times during the circadian cycle, the period of the free-running activity rhythn was altered concurrently with the change in phase induced by the light perturbation. In most instances, phase shifts were transient, but the period changes commonly persisted unless caused to be altered later by another light pulse occurring within a critical period. These critical periods were located over the times of maximum phase-responsiveness to the light, both for phase advance or phase delay in the phase-response curve.

For years, investigators of biological clocks sought means to change the period or in some way stop the clock. During the studies it was assumed that in altering either the period or phase of an observed rhythm the clock was being correspondingly changed. Despite all such attempts, little or no knowledge of the biochemical or biophysical nature of the basic oscillator was gained (see editorial in *Nature New Biology,* 1971).

The clock seemed to be uninfluenced by almost all pharmacological agents that were tested. This list of agents included many dozens of compounds, ranging from metabolic inhibitors of protein synthesis to tranquilizers (Hastings, 1960; Hastings and Bode, 1962; Wahlström and Widerlöv, 1968). However, ethanol Bünning and Baltes, 1963) seemed to alter slightly the period.

Deuterium Oxide (D_2O) has been shown to affect the steady-state period of the circadian rhythm. Suter and Rawson (1968) demonstrated that heavy-water modified the free-running period of the Deer Mouse, *Peromyscus leucopus noveboracensis.* The period of the activity rhythm in constant darkness (DD) increased directly with the concentration of heavy-water added to the animal's drinking water. The response was reversible. This compound has been shown to affect the circadian rhythm of other organisms: the phototactic response of *Euglena* (Bruce and Pittendrigh, 1960), the leaf rhythm in *Phaseolus* (Bünning and Baltes, 1963), and locomotor rhythms of mice (Palmer and Dowse, 1969), pigeons (Snyder, 1969), and blinded rats (Richter, 1970), and the tidal rhythms of isopods (Enright, 1971). Cycloheximide, an inhibitor of protein synthesis, has also been reported to alter the free-running circadian period (Feldman, 1967).

The literature describes many instances of period changes of free-running rhythms. Often an organism being studied in continuous light or darkness is subjected to some experimental procedure after which it continues to be observed under the previous environmental conditions. Frequently, it is noted that the free-running period has been altered. Since this free-running period is postulated to be a direct expression of the clock period it is assumed that the basic timer has been influenced by the procedure. "Spontaneous"

frequency changes are also commonly observed under continuous light (LL) or continuous (DD). These may be abrupt changes or gradual ones.

Harker (1964) reported a spontaneous frequency change in the free-running rhythm of the cockroach *Blaberus*. The activity of the lizard, *Lacerta sicula* (Hoffmann, 1959) showed a period change under constant conditions. DeCoursey and DeCoursey (1964) described sudden frequency changes in the daily rhythm of activity for bats, *Rhinolophus ferrumequinum,* under DD. Such changes are also common for mice (Johnson, 1939; Terracini and Brown, 1962; Brown, 1965), flying squirrels (DeCoursey, 1961; 1964), and arctic rodents (Swade and Pittendrigh, 1967). Palmer (1964) noted them for bird activity rhythms. Among proposed "explanations" have been abrupt physiological changes within the organism, dissociation of rhythms within the animal, and seasonal changes.

Period fluctuations have also been reported under conditions in which they may have been induced in as much in these instances a known stimulus immediately preceded the observed period change. For example, the free-running activity rhythm in the cockroach *Leucophaea* was recorded in DD for 17 days, then in an altered temperature regime, and afterwards in the former DD; a change in frequency resulted (Roberts, 1962). Comparable frequency changes also probably brought about by temperature changes were reported by Enright (1966) for the house finch, Rawson (1960) for bats, and Hoffman (1969) for wild mice.

Experiments involving alterations in photoperiod and in electrostatic field have also been reported to be associated with period changes. Aschoff and Wever (1966) investigating photoperiodic effects on the free-running period of Chaffinches reported this. Dowse and Palmer (1969) described a frequency change following entrainment of mice activity rhythms to electrostatic fields.

The purpose of this paper is to report the induction of frequency changes in the free-running period of Kangaroo Rat in response to brief light perturbations. The Kangaroo Rats were chosen for these experiments because Lowe et al. (1967) reported that the activity patterns of these animals are distinct and have a degree of precision exceeded by few other animals.

Materials and Methods

The test animals were male and female Kangaroo Rats, *Dipodomys merriami*. Eleven subjects were maintained in two types of actographs, running-wheels and tipping-cages (Natalini, 1972). The running wheel actographs had a cage of 1-cm. mesh hardware cloth, 15x25x13 centimeters, with a 35-cm. running wheel. The tipping actographs were made of 1-cm. hardware cloth 13x30x15 centimeters, including a horizontal circular running area and a central nesting area (Boyer and Truchan, 1969). These latter cages were supported near their center on a knife-blade pivot; movement by the rat produced a small amplitude rocking of the cage. Food and water were freely available.

Each revolution of the running wheel, or tilt of the tipping cage, closed a microswitch which caused a pen deflection on an Esterline Angus Event Recorder. This instrument was situated in an adjoining room so its operation and the daily removal of the records would not disturb the Kangaroo Rats.

All the experiments were conducted in a fairly sound-proof photographic dark room. During the experiment, the temperature was 20°C±1°C. The

behavior was recorded from 15 January to 31 August 1970. During this study 66,240 rat-hours of activity were recorded.

Each test organism in its individual actograph was housed in a separate compartment of a large cabinet. There were two six-watt incandescent lamps above each Kangaroo Rat. One provided continuous illumination of an average intensity of 4 lux. The other provided the hour-long light perturbations of approximately 35 lux which were given once every 4 to 7 days at random times within a solar day. The illumination levels were measured with a Weston Illuminator meter (#756) at the usual level of the animal which was approximately three inches from the surface of the shelf.

The Esterline Angus recordings were retraced with consecutive days of data for each individual rat on a single long sheet of tracing paper. The free-running period was estimated by drawing a line through successive onsets of activity. The effect of a light perturbation was determined by comparing the first onset following the light flash with the value expected on the basis of the extrapolation of the apparent preceding period. Each Kangaroo Rat thus acted as its own control, to compensate for the considerable individual variability in response patterns between rats.

Results

The phase-response curves for the pooled data for those eight animals with free-running periods greater than 24 hours and for three animals with periods less than 24 hours have been previously reported (Natalini, 1972).

It became obvious even during the initial stages of this phase-response study that the period as well as the phase often changed suddenly. Observing this fact more closely, it was noted that these changes most commonly occurred near the time of a disturbance such as the experimental light perturbations, feeding interruptions, or cage servicings and especially when such disturbances occurred at, or close to, the times of maximum phase-response. delay or advance, to the light perturbations. These will be referred to as "critical" times.

For a closer observation of this phenomenon, the data were reexamined for the effects on the free-running period of light perturbations or any other recorded disturbances that occurred during a three-hour interval

Table 1.—Disturbances causing Phase Shifts.

Animal	Permanent Phase Shifts With Period Change	Without Period Change	Non permanent Phase Shifts	Total Number of Disturbances	Percent Permanent Phase Shifts
1	4	6	6	16	62.5
2	2	1	6	9	33.3
3	5	1	7	13	46.2
4	1	1	6	8	25.0
5	1	0	4	5	20.0
6	1	5	10	16	37.5
7	1	10	9	20	55.0
8	1	2	5	8	37.5
9	1	4	6	11	45.5
10	0	5	7	12	41.7
11	0	3	8	11	27.3

over the onset of activity and a three-hour one over the end of the activity period. These were considered to be, in general, the critical periods for the Kangaroo Rats. Arbitrarily, no exceptions were made for those individual rats whose maximum phase-response times appeared to have occurred beyond the limits of defined times.

Table 1 gives the percentage of disturbances that occurred during the critical periods that caused permanent phase and/or period change. An abrupt phase-change may, or may not, be associated with a sudden change in period. It also must be emphasized that almost every activity alteration followed a light perturbation but not all perturbations caused a permanent alteration.

Some illustrations of these phase shifts with or without a change in period are presented. These figures are enlarged photographs of small portions of the total activity tracings. The black areas represent the activity near the onset; solid black areas show continuous activity; white areas signify inactivity. Each line is a separate day. For Figure 1, the light perturbation took place 3 hours after onset.

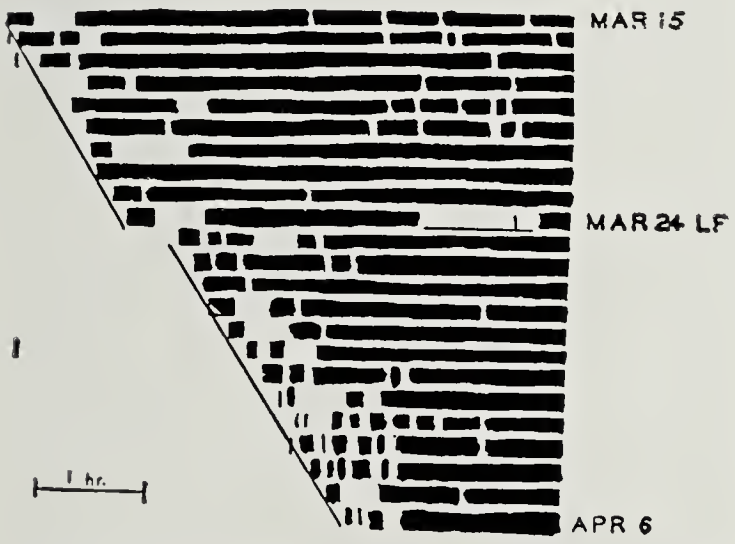

FIGURE 1.—Data of 15 March to 6 April of Animal 1, showing a phase change from a Light Flash (indicated by horizontal line) occurring 3 hours after onset on 24 March; period = 24.13 hours. LF = Light Flash, F = Feeding, N = Noise Disturbance.

The free-running period after the light disturbance remained the same as before, i.e., a phase-shift occurred without a period change.

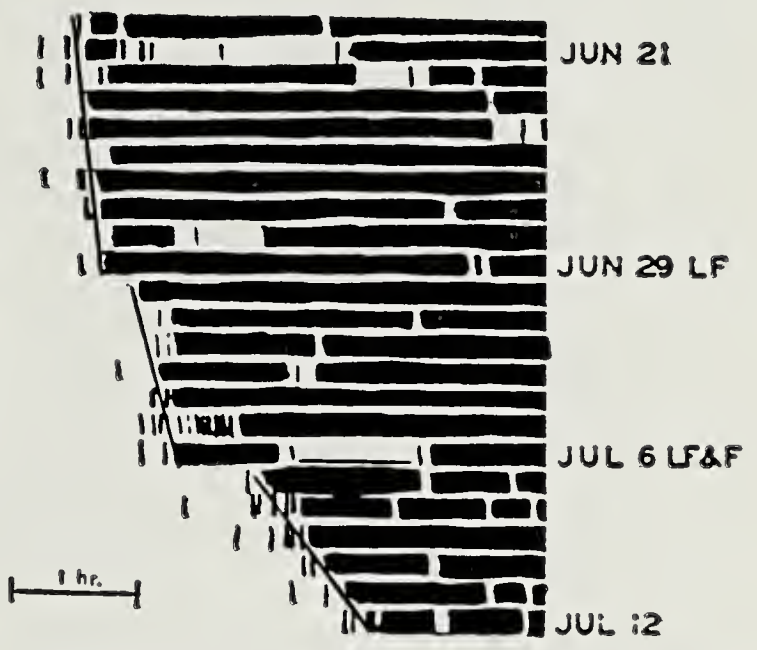

FIGURE 2.—Data of 21 June to 12 July of Animal 7 showing a period change on 29 June from a Light Flash occurring 3 hours after onset (not shown on photograph) (24.05 hours to 24.10 hours) and on 6 July from a Light Flash and Feeding occurring 1 hour after onset (24.10 hours to 24.17 hours). See Figure 1 for abbreviations.

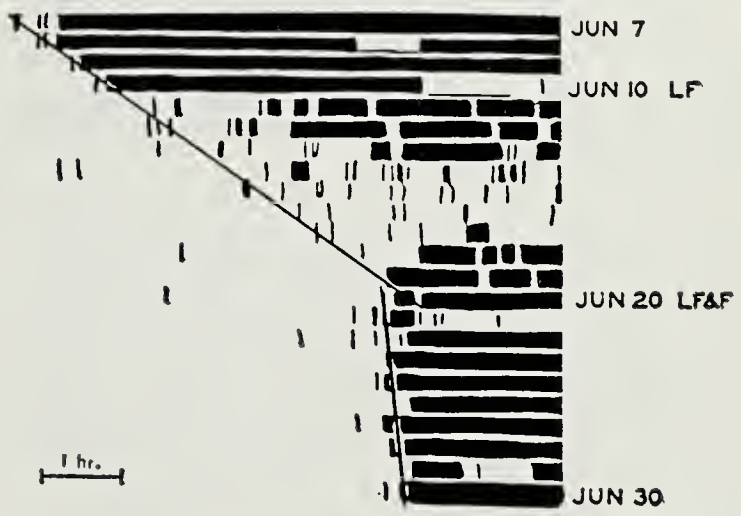

FIGURE 3.—Data of 7 June to 30 June of Animal 7 showing a period change on 20 June from a Light Flash and Feeding occurring at the end of the preceeding activity period (not shown in photograph) (24.33 hours to 24.05 hours); Light Flash on 10 June. See Figure 1 for abbreviations.

Figures 2, 3, and 4 depict a number of examples of period changes. These figures are also enlarged areas of activity records. Most of the animals in the experiment exhibited

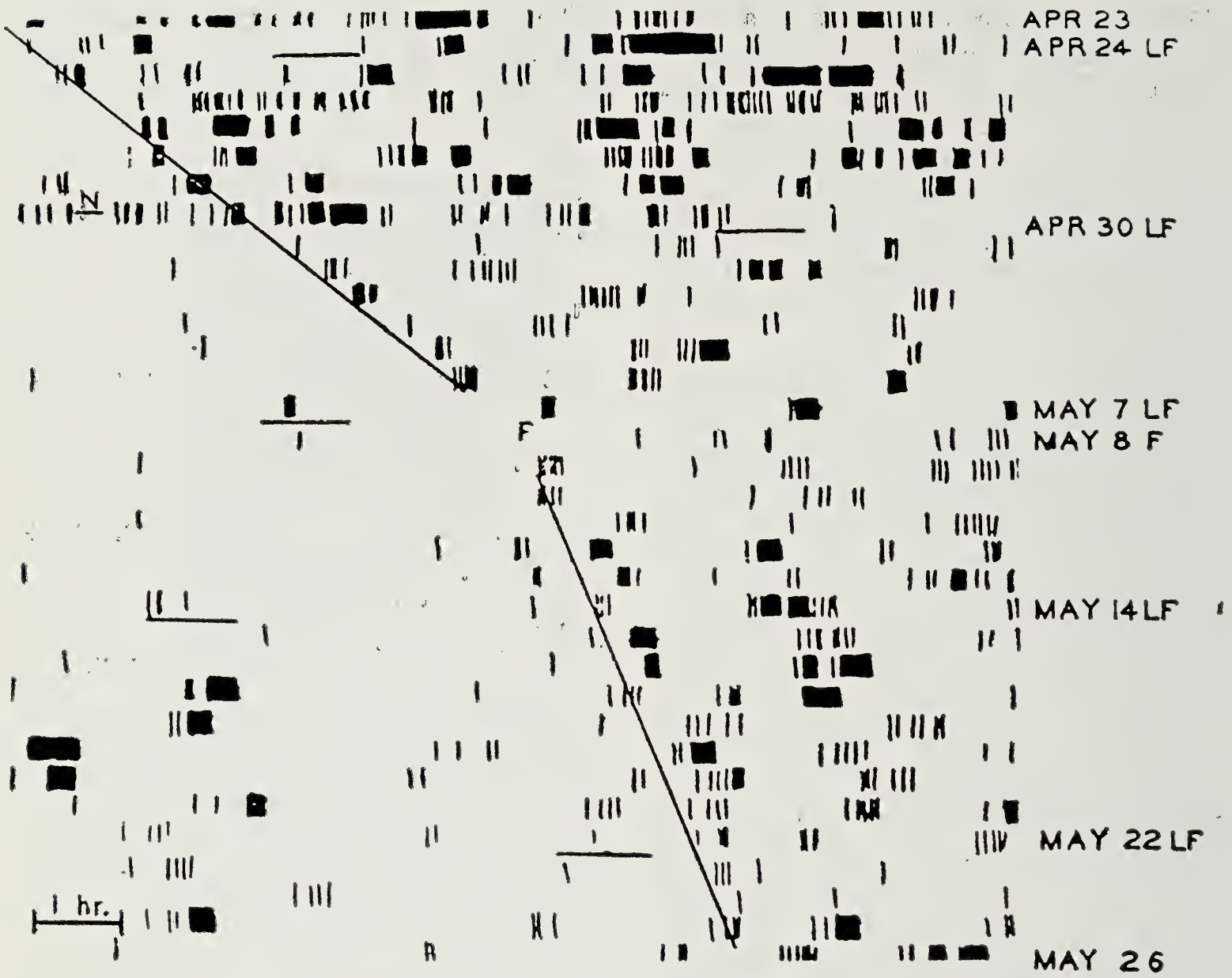

FIGURE 4.—Data from 23 April to 26 May of Animal 11 showing a period change on 8 May from a Feeding occurring at activity onset (24.33 hours to 24.08 hours); Light Flash on 24 April; Light Flash on 30 April; Noise Disturbance over 29 April to 30 April; Light Flash on 7 May; Light Flash on 14 May; Light Flash on 22 May. See Figure 1 for abbreviations.

this phenomenon occasionally. Note that all of the period changes occur when a disturbance such as a light perturbation, feeding or both was applied during what has been termed the critical period. For Figure 2, the light perturbation of June 29th is not indicated on the figure. For Figure 3, the light shock and feeding on June 20th occurred at the end of the preceding activity period also not indicated on the photograph. Notice, the light shock on June 10th (Fig. 4) did not cause any clear period-change; it is outside the critical period. Figure 4 illustrates similar apparent absence of period-change on April 30th and May 22nd in response to light flashes. The feeding on May 8th, within a critical period, effected a change in period.

DISCUSSION

Pittendrigh (1960) termed changes in the free-running period after certain long pretreatments as "after-effects." There are a few conditions reported to cause them, as for example, exposing the animals to an unusual light-dark cycle length such as thirteen hours of light and thirteen hours of dark (13L:13D). When the organism was released into total darkness (DD), the period was found to depend upon the pretreatment. Also, the free-running period in DD ap-

pears related to the light intensity during a pretreatment period in continuous light (LL). Another condition inducing period change involves imposition of a long pulse of light (at least 12 hours duration) within other wise continuous darkness. A final condition inducing such postulated "after-effects" is pretreatment by a 24 hour photoperiod, 12L:12D, preceding release into continuous lighting conditions (LL).

There are only a few instances in the literature where it is reported that short light perturbations might have induced frequency changes. DeCoursey (1964) found that ten minute light flashes sometimes changed the free-running period of the hamster, *Mesocricetus auratus* Kramm (1972) also suggested that short pulses affected the period of activity of the Antelope Ground Squirrel, *Ammospermophilus leucurus leucurus*. A six-hour light pulse changed the frequency of the locomotor ryhthm of the House Sparrow, *Passer domesticus* (Eskin, 1971). Engelmann (1969), similarly, suggested this might occur in *Drosophila* in response to a short pulse (up to 15 minutes) of blue light. A new steady state appeared after the passage of a few transient or temporary period changes. He hypothesized that the light flash caused the new period. However, he recognized that he could not exclude the possibility that he was working with a population of *Drosophila* that may have undergone a genetic change. In all of the above reports, the disturbance was given at or near the previously defined critical period of the phase-response curve. The present study supports the hypothesis that a brief pulse of light can cause an alteration of a free-running circadian rhythm.

Around 50 percent of the times that a light flash occurred within the critical period for Kangaroo Rats, a new steady-state period or phase was induced. These changes lasted for a minimum of about a week. In many cases the reason they lasted only one week was that a later pulse again altered the period or phase. The smallest period change that could be noted with reasonable confidence was about 10 minutes. Not all flashes within the critical period alter the frequencies. It has been shown that the response curve is associated with the animals' circadian or free-running period (Natalini, 1972), and therefore as the free-running period changed so would, presumably, the response-curve. A sensitivity peak within the critical period might even become relocated. An arbitrary interval of three hours was chosen as the duration of the critical period. This could, and probably does, vary among the individual animals. Also, if there were an annual variation in light sensitivity, an annual variation would also be expected in the phase-response curve, and this would be reflected in the amount of period change to any given phasing stimulus.

The circadian rule states that the free-running period varies with light intensity (see: Aschoff, 1960). It may be possible that following light pulses within the critical periods the free-running period does not return fully to its previous frequency but continues at a different circadian period like it would if the light intensity were changed. Since the organism is a physiochemical system and clearly a rhythmic one, the lengthening of one cycle of activity could quite conceivable effect an alteration which would persist for later cycles.

It also seems reasonable to postulate that the time of a light pulse within a circadian cycle would determine concurrently both the amount of phase shift within the cycle and amount of the persistent period change. Consistent with such an hy-

pothesis, Lohman (1967) using the beetle *Tenebrio,* reported that for shifts from one level of continuous light to a higher one (LL_1 to LL_2), the period in the LL_2 was a function of the phase within the phase-response rhythm during LL_1 when the transition occurred.

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GRAPHOLITHA TRISTRIGANA (CLEMENS) (LEPIDOPTERA: TORTRICIDAE) ON NATURALIZED HEMP (*CANNABIS SATIVA* L.) IN EAST-CENTRAL ILLINOIS

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ABSTRACT.—*Grapholitha tristrigana* (Clemens) was found to be the most important parasite on naturalized hemp (*Cannabis sativa* L.) in east-central Illinois. Larvae feed in the pith of stems as well as on developing seeds. Data compiled from field and laboratory studies suggest that larvae destroy an average of 7.1 percent of developing seeds in wild populations of hemp, but rarely kill established plants. Although the insect was present in every stand of hemp examined, up to 75 percent of the larvae were parasitized; parasitoids were *Macrocentrus delicatus* Cresson (Hymenoptera: Braconidae), *Tsmelucha* sp. and *Phacogenes walshiae walshiae* Ashmead (Hymenoptera: Ichneumonidae), and *Lixophaga variabilis* (Coquillett) (Diptera: Tachinidae). *P. walshiae walshiae* has not been reported previously from *G. tristrigana*. Observations on the life cycle of *G. tristrigana* are reported. Evidence suggests that this insect has become an important pest on hemp in this country only within the last 20 years.

During intensive studies of the ecology and drug production of naturalized hemp *(Cannabis sativa L.)* in east-central Illinois, it became apparent that larvae of *Grapholitha tristrigana* (Clemens) (Lepidoptera: Tortricidae) (hereafter referred to, tentatively, as the hemp borer) were the most important parasites of this annual forb. The hemp borer was described first by Clemens (1865) who named it *Stigmonota tristrigana* Clemens. Subsequently, the species was reported by Kearfott (1907) who misidentified it as *Enarmonia saundersana* Kearfott. Heinrich (1926) transferred the hemp borer to the genus *Grapholitha* where it has since remained. He reported the food species to be *Baptisia* spp. and *Lupinus* spp. and cited collections from Ontario, Massachusetts, New York, New Jersey, North Carolina, Florida, Alabama, Illinois, Texas, Kansas and Oklahoma. Additional description of the insect was provided by MacKay (1959) who included hemp as a food species, citing four larval specimens from stems of hemp collected in New York in 1944.

Cannabis, generally considered to be a monotypic genus, is one of the most widely distributed plants. Literature on origin, nomenclature and uses of this dioecious species was summarized most recently by Schultes (1970). Hemp may have been introduced into United States as early as 1629 (Boyce 1900). Brendel (1887) noted that *Cannabis sativa* was "perfectly naturalized and common around Peoria (Illinois) in the year 1852." Haney and Bazzaz (1970) discussed the current distribution of naturalized hemp in Illinois.

METHODS

Intensive field studies were made, primarily in Champaign County, during 1969 and 1970 to elucidate the ecology of naturalized hemp. Observations were focused on 101 strands representing a broad range of site conditions. In autumn 1969, when collected plants were examined in detail in the laboratory, the importance of the hemp borer was realized. During 1970, borers were collected

and reared in the greenhouse and in rearing chambers to determine more of their life cycle and fecundity. Populations in the field were assayed by tallying the number of exit holes in hemp stems of randomly selected stands.

Results and Discussion

From late May until the middle of August, larvae were found in the pith of basal stems of hemp plants. Galleries usually were marked by distinct fusiform swellings of the stems. Exit holes were first observed in the last week of June and increased in number through early August. Sudden increases in numbers of exit holes, indicating maturation of a generation, were not noted. From middle August until frost, larvae were found principally in loose webs around seed clusters and in pith of terminal branches of female hemp plants. During this period, larvae became increasingly active and were frequently found crawling over plants. This was in sharp contrast to the more sedentary behavior of larvae earlier in the growing season.

Based on data from 101 isolated hemp stands, larvae destroyed an average of 7.1 percent of all seed developed. Within these stands, seed destruction by the borer ranged from 0 to 25 percent although no stand was found without the insect. No significant correlation was found between seed destruction by the borer and plant characteristics such as height, stem diameter or seed production. Significant correlations were found between average number of exit holes in stems of female plants and plant height ($r = +0.47$, $P<0.05$) as well as with stem diameter ($r = +0.66$, $P<0.01$). These data support our field observations that more larvae develop in larger plants. Larvae seldom, if ever, resulted in death of plants and they never completely utilized available pith or seeds. Larvae rarely were found on plants less than 25 cm. tall, even when numerous developing seeds were present.

Distribution of larvae within stands was highly irregular and, in early summer, was without apparent regard for the sex of the plant. However, after the middle of August, when seeds were developing, most larvae were found on female plants.

From greenhouse and rearing cage observations, the generation time of the hemp borer is five to seven weeks. Three generations probably are completed each year in this area. The insect apparently overwinters in the soil as a pupa or last instar larva; an intensive search for overwintering insects in stalks and litter revealed none.

Attempt was made to determine the oviposition and number of eggs laid by females mated and maintained in rearing cages. At no time were we able to locate eggs or observe oviposition on the hemp plants in the cage. Adults may be nocturnal. Fecundity estimates, based on the number of resulting first instar larvae, averaged about 17 per female. Data from field stands showed that during a growing season, slightly over four exit holes per hemp plant were cut. This suggests the actual population level of borers in these stands.

The principal population control of the hemp borer was parasitization. Larvae were parasitized up to 75 percent during 1970. Four parasitoid species were identified from our material: *Macrocentrus delicatus* Cresson (Hymenoptera: Braconidae), *Tsmelucha* sp, and *Phacogenes walshiae walshiae* Ashmead (Hymenoptera: Ichneumonidae), and *Lixophaga variablis* (Coquillett) (Diptera: Tachinidae). The braconid, which previously had been reported from *G. tristrigana,* has a known range from Manitoba and Quebec south to Flor-

ida and west to Texas and Iowa. *P. walshiae walshiae* is known only from New Jersey, Delaware, Maryland, Virginia, Pennsylvania, Ohio and Illinois. It apparently was not reported previously from *G. tristrigana* although it is known from *G. molesta* (Busch). The tachinid has been reported from Manitoba to Maine and south to Florida and Texas. It also is known from British Columbia and California (personal communication from Reece I. Sailer).

There was indication in the field that the population of *L. variabilis* tended to increase later in the summer with a corresponding decrease in the population of the Hymenoptera parasitoids. More research is needed to elucidate the relationships between these species.

The biological control of wild hemp rendered by the hemp borer is slight in spite of considerable potential. Extrapolated over three generations, a female could give rise to 1200 larvae, assuming no parasitization or predation, in a single growing season. Larvae collected in the field and reared in the greenhouse on hemp plants destroyed an average of four seeds each during a four week period from early instar to pupation. With this level of seed destruction, one mating pair of borers in the spring potentially could bring about the destruction of 4900 hemp seeds by late summer. This becomes meaningful when we consider that, on the average, each female hemp plant produces about 95 seeds. Seed production is based on seed tallies from 101 wild stands.

Two outbreaks of *Grapholitha* on hemp have been reported from Europe. Nagy (1967) described a rapid increase in the population of *G. sinana* Felder, especially in southeastern Hungary. This insect, according to the author, was autochthonous in Hungary and had been known previously only from wild hops (*Humulus lupulus* L.). Hops belong to the hemp family, Cannabaceae. *G. sinana* also developed in the hemp stem, producing fusiform swellings similar to those we describe, and fed on seeds during late summer. The species was heavily parasitized, up to 20 percent of the eggs and 70 percent of the larvae, but parasitoids were not identified in the publication. Manoliache et al. (1966) reported a similar outbreak in Rumania during 1966 but the insect was identified as *G. delineana* Walker. Again, this insect previously had not been reported in hemp.

It is apparent in the European reports that *Grapholitha* spp. have recently become pests of hemp there. The same is true in this country. It is significant that with intensive research on cultivation of hemp in United States, until about 1945, there is no mention of *G. tristrigana* in the research reports, yet the species now would offer a serious problem to attempts to raise hemp for fiber or seed. The potential of *Grapholitha* spp., as well as their parasitoids, for biological control would justify further research. Additionally, information pertaining to the causes of recent outbreaks of populations in at least two widely separated areas may be important to the understanding of plant-herbivorous parasite relations.

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CHARACTERIZATION OF GOSSYPOL INDUCED ANEMIAS

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ABSTRACT.—A study was made using male rats to determine the possible existence of a relationship between ingested gossypol concentration and the anemia types produced. The dietary levels were: free gossypol, 0.088 and 0.176 per cent; and bound gossypol, 0.055 and 0.110 per cent. The periods of feeding were 7, 14, 21, and 28 days. High levels of free gossypol resulted in hypochromic anemia in animals fed for 28 days. The results showed that the levels of hemoglobin, blood iron and liver iron were inversely related to the levels of free gossypol in the diet and to the length of time the diets were fed.

It has been reported that cottonseed meal is the second most important protein concentrate in the United States in volume of production, and the second most important source of supplementary protein for animal feeding. Nevertheless, limitations have been imposed on the amount of cottonseed meal which can be incorporated into animal feeds. These limitations are due to the presence in cottonseed of a phenolic pigment, gossypol, which is highly toxic to non-ruminant animals.

This toxic substance has been shown to accumulate in the organs of animals and its toxic effects are expressed in a wide array of pathological conditions (e.g., hemorrhagic intestines, hydrothorax, edema of pulmonary tissues, congestion of splanchnic organs, drastic weight loss and anemia).

Danke and Tillman (1965) reported that the ingestion of gossypol by non-ruminant animals will induce anemia, and that a high quality protein diet supplemented with iron can alleviate the anemic response. Their results suggest that gossypol may produce different anemias in the time interval following sustained gossypol ingestion. One type of anemia resulting from an immediate and direct effect of gossypol on the circulating red blood corpuscles may be hemolytic anemia. The other type of anemia (microcytic-hypochromic) occuring later in time may be due to the gossypol blockage of the absorption of some erythropoietic factor such as iron from the gastrointestinal tract or the impairment of erythropoiesis through the cumulative action of gossypol on erythropoietic processes elsewhere in the body.

This study was undertaken to clarify the possible existence of a relationship between the ingested gossypol concentration and the anemia types produced.

MATERIALS AND METHODS

Male rats (28 days of age) of the Holtzman strain were housed individually under uniform conditions of light (10 hr light, 14 hr dark) and temperature (68-72 F). Animals were randomly divided into three diet groups. The control diet (Diet 1) consisted of ground commercial rat chow. Diet 2 consisted of 90 per cent rat chow and 10 per cent ground cottonseed meats (0.088% free gossypol, 0.055% bound gossypol). Diet 3 consisted of 80 per cent rat chow and 20 per cent ground cottonseed meats (0.176% free gossypol, 0.110% bound gossypol).

Each of the three diet groups was represented by 64 animals. The animals in each major diet group were also randomly subdivided into four groups of 16 animals, each subgroup corresponding to feeding intervals of

TABLE 1.—Blood and liver data on rats fed cottonseed meal rations[a]

Days on Diet	7			14			21			28		
Diets	1	2	3	1	2	3	1	2	3	1	2	3
RBCx10^6/mm^3	6.71 ±0.17	5.95 ±0.13[b]*	6.74 ±0.24	6.99 ±0.16	7.01 ±0.12	7.28 ±0.24	7.59 ±0.23	7.16 ±0.22	7.21 ±0.45	7.39 ±0.14	7.70 ±0.14	6.90 ±0.34
Packed cells, %	42.88 ±0.56	41.06 ±0.57*	41.10 ±0.41*	44.20 ±0.44	45.23 ±0.43	44.87 ±0.57	48.21 ±0.72	46.68 ±0.40	45.38 ±0.58	47.54 ±0.56	48.03 ±0.45	46.25 ±1.46
Hb,g/100cm^3	13.05 ±0.75	13.36 ±0.22	13.29 ±0.28	14.02 ±0.16	14.25 ±0.17	14.87 ±0.15	15.13 ±0.30	14.49 ±0.24	14.38 ±0.25	17.20 ±0.52	16.32 ±0.68	11.59 ±0.96*
Mean corpuscular vol , μ^3	64.57 ±2.09	69.44 ±1.76	62.23 ±2.53	63.48 ±1.15	64.69 ±0.93	62.26 ±2.31	64.09 ±1.41	65.90 ±1.60	65.94 ±4.17	64.55 ±1.08	62.78 ±1.18	68.14 ±2.52
Mean corpuscular Hb, $\mu\mu$g	20.70 ±0.77	22.55 ±0.45	19.95 ±0.61	20.13 ±0.46	20.39 ±0.30	20.58 ±0.64	20.09 ±0.46	20.45 ±0.55	20.81 ±1.29	23.35 ±0.74	22.16 ±0.57	16.95 ±1.28*
Mean corpuscular Hb conc , %	32.00 ±0.30	32.66 ±0.78	32.40 ±0.88	31.74 ±0.36	31.52 ±0.27	33.18* ±0.32	31.40 ±0.52	31.06 ±0.48	31.72 ±0.53	36.17 ±0.97	35.37 ±0.57	25.29* ±2.06
Blood Fe, mg/100 ml	35.10 ±0.96	31.26* ±0.98	31.17* ±1.32	34.05 ±0.91	35.72 ±0.69	33.66 ±1.23	37.69 ±1.72	35.05 ±1.06	31.55* ±0.96	39.94 ±1.03	40.74 ±1.31	32.57* ±1.89
Liver Fe, ppm/g wet liver	140.99 ±5.00	129.69 ±4.81	124.04* ±5.20	141.07 ±3.88	144.45 ±5.28	133.28 ±5.10	156.05 ±6.87	141.40 ±4.77	122.48* ±4.25	157.36 ±6.69	165.03 ±6.81	124.85* ±6.55
% NaCl at which 50% hemolysis occurs	0.3595 ±0.0029	0.3863* ±0.0006	0.3566 ±0.0033	0.3735 ±0.0018	0.3644* ±0.0056	0.3753 ±0.0018	0.3796 ±0.0031	0.3930* ±0.0013	0.3950* ±0.0016	0.3812 ±0.0032	0.3903* ±0.0023	0.4034* ±0.0031

[a] Mean values ± SE
[b] * $P < 0.05$

7, 14, 21, and 28 days, respectively. Upon termination of each feeding interval blood was collected from representative animals and processed for total red blood cell count (RBC), hemoglobin content (Hb), percentage of packed cells, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red cell osmotic fragility (Swallen, 1964), and blood iron concentration (Natelson, 1961). Livers were excised and stored at -20 C until analyzed for total iron content (Sandell, 1959).

Results

Results of blood values and liver iron are recorded in Table 1. The erythrocyte count of control animals increased gradually to a maximum count by the end of the third feeding week. A slight decrease at the end of the fourth feeding week is indicated. Diet 2 animals exhibited a decrease in erythrocyte count at the end of the first feeding week followed by a gradual increase through the remaining feeding periods. An increase in erythrocyte count through two weeks of feeding is indicated by Diet 3 animals, with a gradual decline during the third and fourth feeding weeks.

Hematocrit values among control animals showed a similar trend and support the observed increase in erythrocyte numbers during the first three weeks of the feeding period and the observed leveling off thereafter. Hematocrit values for animals on experimental diets generally showed an increase after the first week on diets. The hematocrit values of animals fed experimental diets are significantly lower than the control value at the end of one week on diets. Among Diet 2 animals this decreased hematocrit value may be due to the significantly lower erythrocyte count.

The average hemoglobin concentration of the blood among control animals was found to increase progressively throughout the four week feeding period, and can be accounted for, at least during the first three weeks, to the increase in erythrocyte numbers. In the fourth week of feeding, however, the erythrocyte population did not increase nor did the mean corpuscular volume. Therefore, the increase in hemoglobin during the fourth week must be accounted for by an increased corpuscular hemoglobin concentration. The mean corpuscular hemoglobin concentration is shown to increase between the third and fourth weeks and supports the foregoing relationship. Among Diet 2 animals the average hemoglobin concentration of the blood exhibited a progressive increase throughout the four week feeding period. The average hemoglobin concentration of Diet 2 animals at one week on diet remained within normal ranges although the erythrocyte population was significantly decreased. This is accounted to the increase in mean corpuscular volume and mean corpuscular hemoglobin at this feeding period. Hemoglobin content of animals on Diet 3 showed a similar trend through the first 14 days on diet and then decreased rapidly at 21 and 28 days on diet. A decrease in mean corpuscular hemoglobin and mean corpuscular hemoglobin concentration is also shown among Diet 3 animals at the end of the fourth feeding period.

Mean corpuscular volume among control animals remained stable through the four feeding periods while it gradually decreased among Diet 2 animals. Among Diet 3 animals through the first two feeding periods, the mean corpuscular volume remained stable and gradually increased to a maximum at the end of the fourth feeding period.

Generally after the first feeding period, erythrocytes in all diet groups displayed a decreased resistance to

hypotonic solutions. At the first, third and fourth feeding periods Diet 2 animals were significantly less resistant to hypotonic lysis. Diet 3 animals exhibited significantly less resistance at the third and fourth feeding periods.

Mean blood and liver iron were significantly decreased at the first, third and fourth feeding periods among Diet 3 animals while these values were significantly decreased among Diet 2 animals at the end of the first feeding period.

Discussion

Menaul (1923) determined that gossypol exerts a hemolytic effect on erythrocytes. The presence of a lower erythrocyte count among animals maintained on Diet 2 for seven days suggests the presence of some hemolytic action by gossypol. However, the absence of significantly lower erythrocyte counts at longer feeding periods on Diet 2, and the absence of this condition among animals fed the higher levels of free gossypol in Diet 3 indicate that this effect was not persistent throughout the investigation. Although the animals were in their rapidly growing phase throughout most of this study, it appears that the rations contained adequate protein to compensate for the deleterious effect of gossypol on erythrocyte hemolysis. The increased corpuscular volume at seven days on diet for animals that ingested Diet 2 indicates a higher proportion of younger erythrocytes. This effect would support a compensatory response to a hemolytic agent.

Erythrocytes from animals fed Diet 3 for 28 days were hypochromic which is indicative of an iron deficiency that could result from inadequate absorption of iron, a deficiency in dietary iron or an excessive demand for iron. The blood and liver iron levels among these animals at this feeding were significantly lower. This would support the finding that the iron stores were inadequate to maintain adequate hemoglobin synthesis. It has been known for years that soluble iron salts inactivate free gossypol in the diet (Gallup, 1928). It has been suggested that the iron forms an insoluble gossypol-iron complex in the intestinal tract that is not absorbed. Shieh *et al.* (1968) have suggested in their chelation studies the formation of a 1 to 2 molar ratio of gossypol to ferrous ions. The lower blood and liver iron values exhibited among Diet 3 animals after 28 days on diet indicate the possibility that the free gossypol in the diet chelated with iron in the intestinal tract and caused a reduction in iron absorption.

The increased fragility of erythrocytes among animals fed experimental diets for 21 and 28 days provides evidence of spherocytosis and/or abnormalities in the shape of the erythrocytes. When an erythrocyte is placed in a hypotonic solution it will become increasingly spherical in shape and eventually lyse. Spherocytes (cells that are initially spherical) would expand very little before the cell membrane is stretched and lysis occurs. Thus, spherocytes would have less resistance than normal cells to hypotonic solutions. It has been determined that spherocytes possess a basic intracellular defect in phosphorylation and consequently are less able to maintain their integrity than normal cells (Motulsky *et al.*, 1955). Since gossypol is lipophilic and may penetrate the erythrocyte membrane by diffusion, it may induce an abnormal cell shape through the disruption of some aspect of erythrocyte metabolism (Abou-Donia and Lyman, 1969).

It is also possible that the decreased resistance to lysis of erythrocytes among experimental animals may be due to a direct effect of gossypol on the erythrocyte stroma. The lipophilic gossypol may change the integrity of

the cell membrane and decrease the resistance of the erythrocytes to hypotonic solutions.

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AN EVALUATION OF THE ADVISABILITY OF THE RELEASE OF THE GRASS CARP, *CTENOPHARYNGODON IDELLA*, INTO THE NATURAL WATERS OF THE UNITED STATES

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ABSTRACT.—A review of the literature concerning the biology of the grass carp, *Ctenopharyngodon idella*, is presented, including information on the usefulness of this species as an agent to control aquatic vegetation. Feeding habits, digestion, reproduction, age and growth, physiological requirements, and interactions with other species are described. The advantages and disadvantages of the release of the grass carp are presented and recommendations concerning future control of this species are made.

The grass carp, *Ctenopharyngolon idella* Valenciennes, has recently received considerable attention from various state and federal agencies as a potential means of controlling noxious aquatic plants. This heightened interest necessitates a thorough evaluation of the probable impact of new introductions of this species on the native fish fauna of the United States.

The grass carp, *Ctenopharyngodon* white amur or Waan Ue, is native to the rivers, lakes and ponds of Siberia (Amur Region), Manchuria and China, southward to the Chu River, South China. It has been introduced for pond culture into Formosa, Malaysia, Japan, Viet Nam, Thailand, Hong Kong, Ceylon, and India as well as into the U.S.A., Great Britain, Israel, eastern Europe, Germany and Holland (Cross, 1969; Kuronuma, pers. comm.; Lin, 1935; and Steven son, 1965).

In the United States the grass carp was first introduced by the Bureau of Sport Fisheries and Wildlife to the Fish Farming Experimental Station, Stuttgart, Arkansas in November, 1963. The grass carp has been introduced into five state-owned fishing lakes in Alabama, cultured at the Marion Fish Hatchery, Alabama, maintained at Auburn University, Alabama, planted into an irrigation pond at Tucson, Arizona, kept in artificial ponds in Arkansas, and at Oregon State University. Three grass carp, weighing about 20 pounds each (4 years old), have already been taken in the Mississippi River, two from as far north as southern Illinois. (St. Louis Post Dispatch, Feb. 9, 1971). There is no evidence that these introductions have resulted in any established wild populations in the United States.

CONTROL OF AQUATIC VEGETATION

Nair (1968) cites numerous references attesting to the ability of the grass carp to control the growth of aquatic plants. Cross (1969) presents a table listing the various plants eaten by the grass carp, in the approximate order of their preference. Avault (1965) presented data on its herbivorous habit in ten experimental pools, which had each been planted with 12 species of aquatic plants. Each pool was stocked with a single grass carp, 12 to 16 inches long, equalling 685/acre. Within two to three weeks complete control was obtained. Stevenson (1965) reports that six fish averaging 908 grams were placed in a 0.25 acre pond (24/acre) containing *Chara, Najas, Eleocharis,* and *Polygonum.* In two months the aquatic plants were reduced but not eliminat-

ed, but the fish were also supplied with commercial feed. In a second pond (0.1 acre) containing *Chara, Najas,* and *Anacharis,* three fish, approximately 1,270 grams each, were introduced. Two months later the *Chara* and *Najas* had been removed but the Anacharis remained and an abundant growth of *Spirogyra* was present. Commercial feed was also supplied to this pond. McConnell (pers. comm.) reported that forty 2-inch fingerlings were introduced in a two-acre pond on a Tucson, Arizona, golf course and that "after the first year they were very effective in keeping the pond free of undeisirable weed growth". McConnell also reported that a single grass carp was transferred to a ½-acre pond which was weed-choked, Although it did not completely control the weeds, its grazing caused a noticeable reduction in weed density.

Feeding Habits

All of the above mentioned studies have been conducted with adult or subadult individuals, in artificial ponds or lakes. Lin (1935) in a study conducted at the West River in the interior of Kwangsi Province, China, reports "Its omnivorous feeding habits are well known. The Waan Ue eats grass, leaves of trees, and water plants as well as small fish, earthworms, silkworm pupae, beef, insects and even decayed cloth and shoes". Hora and Pillay (1962) reported that the fish is an omnivore eating chopped fish, flesh of freshwater mussels, and silkworm pupae along with aquatic vegetation. Stevenson (1965) reports that fingerlings fed heavily on *Daphnia,* and chopped earthworms were eaten in large quantities. Chironomid larvae were also highly preferred. Stevenson (1965) further states that in one pond the fish fed on zooplankton to the exclusion of algae and commercial feed. Cross (1969) reported that in his laboratory, grass carp about nine inches in length ate *Daphnia,* tubifex worms and *Asellus* as well as vegetation. Nikolskii (1954 and 1956) reports that the young of the grass carp feed on crustaceans, rotifers, and chironomid larvae. It has been suggested by Stevenson (1965) that in pond situations the grass carp may be forced to feed exclusively on aquatic vegetation and thus any preference for other foods would not be seen.

Recent studies at Auburn University by R. H. Kilgen and R. O. Smitherman (pers. comm. and 1971) have dealt with the feeding habits of the grass carp in pond situations where other species of game fish were present. A comparison of the stomach contents of the grass carp indicated that 84% of its food consisted of macrophytes, 9% insects, mostly chironomid larvae, and 7% Purina Trout Chow. The largemouth bass, spotted bass, redeye bass, Israeli carp and channel catfish in the pond fed mainly on insects. The presence of high percentages of insects in the stomachs of the species other than the grass carp indicates that animal food was available but that the grass carp fed mainly on plant material. Tang (1970) has indicated that in the absence of competition or when the supply of macrophytes is low the grass carp will switch to food items other than aquatic plants.

Digestion

Hickling (1966) reported that the digestive tract of the grass carp is extremely short for a herbivorous fish and that at a temperature of 28° to 30° C, the food passes completely through the fish in less than 8 hours. Digestion is incomplete, with about ½ of the food material passing through undigested. Hickling (1966) states that this undigested food can support, directly or indirectly, a large biomass of other species of fish. Stroganov (1963) reported that the

feces of the grass carp promotes vigorous growth of plankton. Due to the incomplete digestion, the grass carp must consume large quantities of food and this, of course, is the reason for its usefulness in controlling aquatic vegetation.

Reproduction

Lin (1935) and Kuronuma (pers. comm.) reported that spawning takes place in the center of large rivers with currents of 3.3 to 5.5 feet/second usually just below extensive rapids. Nikolskii (1956) states that a current flow of between two and five feet per second is required. The temperature required for spawning is 26-30° C according to Lin (1935) and above 20° C, Nikolskii (1956). In addition to these requirements, spawning takes place after a sudden rise in the river, usually after heavy rains. Lin (1935) stated that a rise in excess of 4 feet within a 12-hour period is necessary for spawning to occur. Presumably, spawning during periods of high turbidity reduces predation on the semi-pelagic eggs. This species undergoes a spawning migration, usually in large shoals, with spawning occurring from April to mid-August. Most of the spawning in the West River, China, occurs from the end of May to mid-June.

Lin (1935) reported that a 16-pound female contained 100,000 eggs, but felt that all of the eggs were not spawned at one time. The eggs are semi-pelagic, floating downstream in the mid-layers of the water (Kuronuma, pers. comm.). Lin (1935) reported that hatching takes place 34 hours after fertilization, while Tang, Hwang and Lin (1963) gave a figure of 24 to 30 hours at 25° C. Within a short time the larvae are swimming actively and begin feeding on ooplankton and to a lesser extent phytoplankton.

Generally, grass carp have not reproduced in pond situations outside their natural habitat. However, this species has been reported to have spawned in Japan (Anon., 1961) and in Taiwan (Tang, 1960). Spawning has been induced in pond situations by injections of fish pituitary extracts (Tang *et al.*, 1963 and Alikunhi, Sukumaran and Parameswaran, 1963).

Age and Growth

Lin (1935) found that most of the grass carp in the West River, China, were about four years old and that none of the mature fish were less than three. Females were larger than males, reaching a length of about three feet. Cross (1969) reported that the fish takes between five and nine years to become sexually mature. Stevenson (1965) presented data showing a weight of 4 grams and a length of 8 cm at 6 months, 372 gm and 28 cm at 12 months and 1,816 gm and 50 cm at 18 months. He also indicated the following age at first maturity for various areas.

Russia	
8-10 years	2.7- 3.8 kilograms
S. China	
4	6.0
Israel	
5-8	8.0-10.0
Malaysia	
10-14 months	2.0- 5.0

Kuronuma (pers. comm.) indicated that the rate of growth of the grass carp is two to three times that of the common carp, *Cyprinus carpio*, under similar environmental conditions. The grass carp attains the size of 1.5 meters in length in river waters within five or six years. Hooper (pers. comm.) stated that in Alabama lakes grass carp stocked as two year olds grew up to 6 pounds the first year.

Physiological Requirements

Cross (1969) summarized the physiological requirements of the grass

carp as follows: "It is able to withstand a wide range of water temperatures from 0 to 35° C (Stevenson, 1965), can tolerate salinities as high as 10,000 p.p.m. (Doroshev, 1963) and can withstand oxygen concentrations as low as 0.5 p.p.m. (Yeh, 1959)." Stevenson (1965) noted that in one of his experimental ponds, in which the temperature fell to 0° C and a heavy ice cover formed which lasted five weeks, the grass carp showed no ill effects.

Interactions With Other Species

Kuronuma's (pers. comm.) studies have shown that the production of *Carassius auratus* and small shrimp was not affected by the existence of grass carp in farm ponds in Japan. McConnell (pers. comm.) found that grass carp did not noticeably interfere with a November to April put and take fishery in Arizona. The trout grew well despite the presence of an estimated 300 lbs./acre of grass carp. He has also stated that "During every spring in which grass carp were present in the pond we introduced brood stock of *Tilapia zillii*. Extremely dense populations of *T. zillii* were always produced by the following winter. Apparently there was no significant negative interaction between these species". Nakamura *et al.* (1954) found that in Japan the addition of the grass carp to ponds did not interfere with production of other fish species.

Kilgen and Smitherman (1971) in analyzing the food habits of grass carp in combination with largemouth bass, spotted bass, redeye bass, Israeli carp and channel catfish found that the overlap in food items was relatively little. Kilgen and Smitherman (pers. comm.) evaluated the growth rates of channel catfish and striped bass when stocked with grass carp at rates of 40 to 80 per acre and found no detrimental effects when compared with control ponds. Smitherman (pers. comm.) has evaluated the effects of grass carp (20 or 40/acre) on largemouth bass-bluegill, largemouth bass-bluegill-shad and fathead minnow-walleye-bluegill populations. The survival of walleye, threadfin shad and fathead minnows was erratic in the experimental ponds. The presence of grass carp at either 20 or 40 fish per acre did not greatly affect survival of fingerling bluegill or largemouth bass. Considering growth rates, comparing ponds with no grass carp with those containing grass carp at a rate of 40/acre, Smitherman found that the bass-bluegill in the control averaged 159.73 lb./acre, while in the ponds with the grass carp the weight was 119.15 lb./acre. This could be interpreted as a competitive effect on the growth or reproduction of the bass and bluegill, but Smitherman feels this is the result of greater survival of young bluegill in the ponds where the vegetative cover had not been removed by the grass carp.

Advantages of the Release of the Grass Carp

The grass carp, when stocked at high enough densities, may serve as an effective biological method for the control of noxious aquatic plants. The presence of an effective biological control would eliminate the necessity of utilizing chemical controls and reduce the potential of environmental contamination. The Alabama State Conservation Department Hatchery at Sartaboga, Alabama, has experienced an increased fingerling bluegill production when using grass carp versus chemicals for weed control (Hooper, pers. comm.). In terms of economics ,the use of a biological control should be less costly than the use of chemical or mechanical clearing. However, if hatchery rearing and pituitary injections are necessary to maintain the species, the cost would be increased.

Cross (1969) reported that in the commercial fish farms of eastern Europe, grass carp are reared primarily as a food and only secondarily as a weed clearing agent. He also reported that he found the flesh to be very pleasant. Hooper (pers comm.) has indicated that the fishermen in Alabama have found the grass carp to be an excellent sport fish and to have outstanding eating qualities. Smitherman (pers. comm.) has indicated that the flesh of the grass carp is bony but excellent in flavor.

Disadvantages of the Release of the Grass Carp

The major question concerning the further release of the grass carp into the natural waters of the United States is its impact on the native fish fauna. Concerning the adult grass carp, direct competition with native fish does not seem to be a major problem, for it does not appear to have an ecological counterpart among the native fishes. Also, it does coexist with a natural fish community in Asian freshwaters. However, the ecosystem of Asian freshwaters may differ basically from that in the United States and the effects on the native fauna cannot be entirely predicted.

Indirect competition resulting from the removal of aquatic vegetation may, however, presen ta problem. Aquatic vegetation provides shelter and spawning areas for many native freshwater species and while the removal of aquatic vegetation from choked ponds may be desirable, the removal of such vegetation from rivers might reduce suitable spawning areas. The removal of aquatic plants by the grass carp in areas where food plants for water fowl have been established would pose a serious threat to water fowl management programs. Another consequence of the removal of aquatic vegetation concerns the fact that many species of fish utilize invertebrates which in turn are found on or around aquatic vegetation. In this respect competition could be direct. Smitherman (pers. comm.) in evaluating the grass carp for weed control stated, "All ponds except F-22 to -24 were entirely free of weeds, with bottoms nearly as clean as those in newly constructed ponds.... The bottoms of F-25 and F-27 were even cleaner than ponds with the lower stocking rate of grass carp; evidently the fish dug into the soil to obtain roots of the midget sedge and other plants".

The young grass carp, as mentioned previously, would be in direct competition with the young of other species of native fish, since they feed mainly on invertebrates.

One other problem relates to the studies which have been conducted on digestive rates. Both Hickling (1966) and Stroganov (1963) have discussed the fact that the undigested food is returned to the water and can be utilized by other organisms. With this release of nutrients into the water, one could predict an increase in productivity perhaps leading to eutrophic conditions in some cases.

If reproduction were to occur in our larger rivers, it is possible that the grass carp might multiply uncontrollably. One need only to look at the common carp, *Cyprinus carpio,* for a graphic example. It is probable that once established it might be extremely difficult to control.

Recommendations

Several workers have already urged extreme caution in introducing the grass carp into our native waters: Stevenson (1965) "Although it would appear that the grass carp is an ideal fish to serve as a biological control for aquatic weeds, great care should be exercised and extensive studies made before the fish is released in natural waters"; Ling (1960), "But the possibility of having it become another major problem fish like the

common carp is so great that unless the fish can become acceptable to the Americans its introduction should not be done hastily"; Cross (1969), ". . . but tests will have to be performed here before any decision on the use of this fish can be taken"; Kuronuma (pres. comm.), "It may be recommended that careful evaluation be made to weigh the effective uses of the species as a biological weed controller in fish ponds against the probable impact to the lives of native freshwater species in the United States".

I will add my voice to those who urge caution concerning further introductions. Perhaps in light of the recent captures in the Mississippi River, this caution is already too late. Smitherman (pers. comm.) reported that he and his colleagues at Auburn University are investigating the possibility of developing a monosex population which could be utilized for stocking in areas where the fish might escape to open waters. Investigations of the relationship between the addition of large amounts of undigested feces and eutrophication should also be made.

Studies at Auburn University have dealt extensively with the interactions between the grass carp and various game species, however, the majority of the fish fauna of the Mississippi drainage is not composed of these larger game species but rather the suckers, minnows, darters, and other species which in the past have been considered as "trash species". With the welcomed new-found interest in environmental quality has come the realization that the native non-game fish species are a valuable resource which must be preserved. Studies involving competition of the young grass carp with the young of native non-game species should be performed as well as studies on the direct effects of the adults on non-game species. All of the studies involving interactions of the grass carp with other species have been conducted in ponds and reservoirs, however, the potential danger to native species lies in the grass carp becoming naturalized in streams.

It is my opinion that until these studies have been made, the risks are too great to allow importation and release of the grass carp.

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CROSSBREEDING AND IMPROVEMENT OF THE FIRST YEAR RECORD OF EGG PRODUCTION IN THE FAYOUMI CHICKENS

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ABSTRACT.—Crossbreeding the Egyptian Fayoumi chickens with three standard breeds, namely the White Leghorn, the Rhode Island Red and the Barred Plymouth Rock, resulted in marked improvement in egg production. Such improvement was the highest in crosses between the Fayoumi and the Barred Plymouth Rock. The differences were statistically significant. Whenever the sire was from a higher laying breed than the dam, the resulting crossbred pullets laid more eggs than the reciprocal cross. These differences may indicate that certain sex-linked genes are involved in the inheritance of egg number. Spring hatched pullets laid fewer eggs than the fall hatched group and the differences were highly significant. In general, Fayoumi crosses seemed better adapted to Egyptian conditions and laid more eggs than the standard breeds or their crosses. Furthermore, the local (Egyptian) consumer apparently prefers the taste of eggs and meat of Fayoumi and its crosses to that of the standard breeds and their crosses.

In the last few decades, the sharp increase in the human population of Egypt has imposed a great demand for more market eggs. Crossbreeding poultry for egg production was suggested as an efficient method for a quick increase in home production (Hutt, 1949; Jull, 1952), especially at the small farmer's level. This method of breeding has been fully studied in the world's great centers of egg production, yet in many countries this question still attracts the attention of the polutry breeder. In such studies the main objective is to discover those breeds and/or varieties which combine best. A few such trials were done on the Egyptian strains of chickens from the standpoint of egg production (Assem, 1951; Mostafa, 1958; Abdel-Gawad, 1955, 1961). The present study is an attempt to evaluate the effect of crossbreeding the Egyptian Fayoumi chickens with three standard breeds based on the first year record of egg production.

MATERIAL AND METHODS

The present study was done on the University of Alexandria flock which included the indigenous breed Fayoumi as well as three standard breeds of chickens, the Single Comb White Leghorn, the Rhode Island Red and the Barred Plymouth Rock. The four breeds were crossed in all possible combinations; each cross, it's reciprocal, and the purebreds were all produced simultaneously.

Crossing began early in the fall of 1958 and continued throughout the spring of 1959. Eight pens of females from each of the four breeds were used. Eight males from each breed were distributed at random among two pens of females from each of the four breeds. There were thus a total of sixteen combinations; six crosses, their six reciprocals, and four purebred controls.

The crosses will be referred to by two letters, the first of which stands for the sire's breed and the second for that of the dam. The breed abbreviations are "F" for the Fayoumi, "L" for the S.C. White Leghorn, "R" for the Rhode Island Red, and "B" for the Barred Plymouth Rock.

All parent stocks were hatched during the previous season (1957/58). The number of pullets in each pen differed according to breed; there were

eighteen Fayoumi, eighteen Leghorn and thirteen Rhode Island Red pullets in each pen occupied by these three breeds. Because of a shortage in mature Barred Rock pullets, pens of this breed contained only seven or eight pullets in the fall with the number increasing to fourteen during the spring hatches.

Eight hatches were produced, five in the fall and three in the spring. The fall chicks were hatched on November 14 and 21 and on December 5, 9 and 26, 1958. In the spring they hatched on April 10, 17 and 25, 1959.

All chicks were brooded for the first two weeks in starting electric battery brooders. They were then transferred to the floor of a permanent gas heated brooding house. After the brooding period, the females were transferred to rearing houses through the fourth month of age. There were 507 and 237 pullets from the fall and spring hatches, respectively. Before they reached the fifth month of age, each season's group was housed separately in a laying house equipped with trap nests.

All pullets were trap nested for the first laying year. Culling was limited to sick pullets or those removed because of accidents.

All the data were subjected to the analysis of variance and the F-test of significance. Any population with less than five pullets was excluded. The differences have also been tested by the least significant difference test.

Results and Discussion

Data on the total number of eggs

Table 1.—Total Number of Eggs in the First Year.

Population	Fall No. hens	Fall Mean Eggs	Spring No. hens	Spring Mean Eggs	Total No. hens	Total Mean Eggs	± S.E.
FL*	38	134.9	23	113.9	61	127.0	± 2.9
LF	19	145.1	5	136.6	24	143.3	± 3.2
FR	32	159.1	15	141.7	47	153.6	± 2.8
RF	44	143.0	12	117.5	56	137.5	± 2.9
FB	9	185.4	2	101.5	11	171.1	± 4.8
BF	12	149.7	7	123.3	19	139.9	± 4.2
Fay. crosses mean	—		—		218	140.6	± 1.8
LR	24	160.2	2	97.5	26	155.3	± 3.1
RL	67	160.1	7	118.3	74	147.1	± 2.1
LB	8	150.6	1	98.0	9	144.8	± 4.3
BL	24	130.3	10	108.3	34	123.8	± 2.8
RB	15	161.5	18	118.1	33	137.8	± 2.9
BR	27	139.7	1	83.0	28	137.6	± 3.0
Standard bred crosses mean	—		—		204	138.9	± 2.0
Leghorn	10	142.5	16	141.3	26	141.8	± 2.6
Rhode I. R.	19	122.5	17	100.2	36	112.0	± 2.7
B.P.R.	7	110.1	13	67.5	20	82.5	± 4.2
Standard breed mean	—		—		82	114.2	± 2.5
Fayoumi	31	127.6	28	118.6	59	123.4	± 2.8
General mean	386	144.1± 1.1	177	115.8± 1.8	563	135.2	± 1.8

*First letter stands for male breed and second for female's.

laid in the first year are summarized in Table 1. The general mean was 135.2 ± 1.8 eggs for the 563 pullets raised in the present experiment. This was a low average if compared to the present day standards of laying in the domestic fowl. However, it was not much lower than the figures published on local flocks which were raised under similar conditions of husbandry (Assem, 1951, and Abdel-Gawad 1955 and 1961).

Two explanations may account for this low productivity. First, the present observations on egg number were the first recorded on the University flock since its founding, and there had been no chance for selection for this trait. Therefore, no information was available as to the egg production potential of the parental stocks of this flock.

The second explanation might be the low nutritional level of the feed these pullets received during their growing and production periods. The main difficulty in this respect was the scarcity and irregular supplies of animal protein and other feed supplements. However, it is evident that since we are interested in the relative merit of crosses and purebreds, it is justifiable to use the present data as all the populations secured had comparable environmental conditions.

Differences between these populations were found to be highly significant (Table 2), a fact which indicates that the breeds differed according to their combinability in the production of F_1's.

TABLE 2.—Results of the Analysis of Variance of the First Year Egg Number.

Source of Variations	D.F.	Mean Square
Total	488	—
Between populations	11	10871.4**
Between seasons	1	72796.4**
Populations X seasons	11	1339.3
Within populations	465	1402.6

**Significant at 0.01 level.

Comparing the Fayoumi breed with the other three standard breeds, the Fayoumi averaged 123.4 ± 2.8 eggs per year versus 114.2 ± 2.5 eggs for the other three breeds. But the difference was not statistically significant (Table 3). The Leghorn exceeded Fayoumi in this aspect as its mean was 141.8 ± 2.6 eggs, while the Fayoumi exceeded both the Rhode Island Red and the Barred Rocks, since the two later breeds averaged 112.0 ± 2.7 eggs and 82.5 ± 4.2 eggs respectively. Assem (1951) reported 156.4 eggs for the Fayoumi per year which is higher than that observed in our flocks. This difference between the two flocks could be due to strain and/or management.

While the annual egg production mean in the Fayoumi was 123.4 ± 2.8 eggs, its crosses with the standard breeds laid 140.6 ± 1.8 eggs on the average. Abdel-Gawad (1955) found similar results and concluded that the Fayoumi crosses were higher than the pure Fayoumi in egg production. She reported 164.2 eggs for RF cross and 152.7 eggs for Fayoumi pullets. Fayoumi crosses produced more eggs when the male was of the higher producing breed than the dam. Their means were 153.6 ± 2.8 and 171.1 ± 4.8 eggs for FR and FB crosses, respectively. The reciprocal crosses had lower means of 137.5 ± 2.9, and 139.9 ± 4.2 eggs for RF and BF, respectively. Similarly, when the Leghorn was the sire, we observe that the LF cross laid 143.3 ± 3.2 eggs, which was more than the reciprocal (FL) that laid 127.0 ± 2.9 eggs only.

These results did not agree with those of Mostafa (1958). He reported in the Fayoumi crosses that reciprocal combinations laid about the same number of eggs. In general, even the standard-bred crosses follow the statement, that whenever the

sire was from a higher laying breed than the dam, the crossbred pullets laid more eggs than the reciprocal cross. This may be interpreted as the effect of sex-linkage. Such linkage was also suggested by Niesel (1948), and King and Bruckner (1952) who stated that sex-linked genes are involved in the inheritance of egg number.

Fayoumi crosses averaged 17.2 eggs more than did the Fayoumi itself, and this difference was highly significant (Table 3). Similarly, the standard-bred crosses exceeded the standard purebreds with 24.7 eggs more, which proved to be a highly significant difference. Generally, it is evident that the crossbred pullets laid more eggs than the parental purebreds, as the Fayoumi crosses and standard bred crosses averaged 140.6 ± 1.8, and 138.9 ± 2.0 eggs respectively, versus 114.2 ± 2.5 eggs for the three standard purebreds and 123.4 ± 2.8 eggs for the Fayoumi. This agrees with the results reported on Fayoumi crosses by Nordskog and Phillips (1960) as well as those who worked in crossbreeding trials (see Hutt, 1949; Jull, 1952). Comparing the Fayoumi crosses with the standard bred crosses, the former laid more eggs but the difference was insignificant.

Heterosis in the F_1's was estimated in the present study by calculating the difference between the average of the two parental purebreds and that of the two reciprocal crosses. This difference was expressed in per cent of the parental mean. The results of these calculations are shown in Table 4, from which it is evident that there is a heterotic effect secured by crossing, especially when the Fayoumi was crossed with the standard breeds. Heterosis was low when Fayoumi and Leghorns were crossed (1.92%). But when Fayoumi was crossed with Rhode Island Red or Barred Rocks, higher heterosis resulted than from the crossbreeding between the standard breeds.

The fact that crosses between Fayoumi and Leghorns showed lower heterosis than any other group may be an indication that the difference between the strains used of these two breeds is not great, as they are both light breeds. The gap between the strains used from the Fayoumi and the two heavy breeds Rhode Island Red and Barred Rocks was apparently great enough to induce such large heterosis (Table 4). The same effect was suggested by Hutt (1949) in

TABLE 4.—Percentages of Heterosis in the First Year Egg Number.

Populations	Difference observed $\bar{X}F_1-\bar{X}P_1$	Heterosis $\frac{\bar{X}F_1-\bar{X}P_1}{\bar{X}P_1}$
FL and LF	+ 2.55	1.92%
FR and RF	+27.85	23.66%
FB and BF	+52.55	51.04%
LR and RL	+24.30	19.15%
LB and BL	+22.15	19.75%
RB and BR	+40.55	41.70%

TABLE 3.—Least significant differences in total first year egg Number.

Populations	No.	L. S. D. at .05 level	L. S. D. at .01 level	Difference observed
Fay. and Standard purebreds	141	13.4	—	9.2
Fay. and its crosses	277	11.4	15.1	17.2**
Standard purebreds and their crosses	286	11.0	14.5	24.7**
Fay. crosses and standard bred crosses	422	8.6	—	1.7
Fall and spring	563	7.2	9.5	28.3**

**Significant at 0.01 level.

comparison between breed and strain crosses.

The difference between the purebred Fayoumi and its two reciprocal crosses was estimated in per cent of the Fayoumi mean. For this percentage the term "improvement over Fayoumi" is used hereafter. Table 5 summarizes the improvement percentages in the first year egg record.

TABLE 5.—Percentages of improvement in the First Year Record of the Crosses over that of the Purebred Fayoumi.

Populations	Difference observed $\bar{X}F_1 - \bar{X}$ Fay.	Improvement over Fayoumi $\frac{\bar{X}F_1 - \bar{X} \text{ Fay.}}{\bar{X} \text{ Fay.}}$
FL and LF	+ 11.75	9.52%
FR and RF	+ 22.15	17.95%
FB and BF	+ 32.10	26.00%

The crosses between Fayoumi and Barred Rocks attained the highest improvement (26.0%) followed by the crosses between Fayoumi and Rhode Island Red (17.95%), the lowest improvement was secured in the case of crosses between Fayoumi and Leghorns (9.52%). This also indicates to some extent that the lines used from these breeds differ in the relationship to each other. This was in agreement with Maw (1941) who observed that the improvement over the parental lines tended to vary according to the degree of relationship between the parents.

It should be made clear that the data obtained in the present study reflect the performance and genetic potential of the strains used. Therefore, any conclusions concerning which breeds might be most successfully crossed or percentage of heterosis and improvement apply only to the specific sample of the breeds crossed in this experiment which may or may not be typical of the breeds involved as a whole.

In Table 1, the data was classified according to seasons as well as to populations, since the populations were hatched both in the fall and the spring. It has been tested statistically with two different methods, the analysis of variance according to the "F test" (Table 2) as well as the least significant difference method (Table 3). Both tests gave the same results. The pullets which were hatched in the fall averaged 28.3 eggs more than did the spring hatches as their means were 144.1 ± 1.1 eggs and 115.8 ± 1.8 eggs, respectively (Table 1). This difference was highly significant (Tables 2, 3).

Various strains of the standard breeds have been repeatedly introduced in the past four decades by Egyptian breeders and breeding stations. Since their introduction, it has been noticed that the local customer prefers the taste of indigenous breed eggs and meat over that of the standard breeds. By comparison with the standard breeds, Fayoumi chickens are generally smaller in size, lay their first egg earlier, and as a consequence lay smaller eggs than that of Leghorns or the heavy breeds (Abdel-Gawad, 1955, 1961; Mostafa, 1958; Nordskog and Phillips, 1960). Both eggs and meat of the Fayoumi are characteristically stronger in flavor than the standard breeds. The relatively small Fayoumi eggs contain bright golden yolk that is usually darker in pigmentation than that of the standard breeds. Furthermore, the meat of the indigenous Fayoumi chickens is darker in color and firmer in texture and is somewhat similar in taste to wild (game) fowls. The darkness of its meat color may be correlated with higher melanin content since its shanks are characterized with dark melanin color that extends sometimes to the meat in the lower portions of the thighs.

In a pioneering experiment (El-Ibiary, 1961), a taste panel compris-

ing a group of Americans and Egyptians sampled eggs and meat of both Fayoumi and the standard breeds after being prepared in the same way. Invariably, the Americans preferred the taste of eggs and meat of the standard breeds while the Egyptians preferred that of the Fayoumi. Even-though the experiment lacked adequate controls and the data was quite limited, the visual trend was strongly indicative of definite taste differences. Therefore, more experimental data on this line should be obtained before a final conclusion is made.

The problem then is not a quantitative increase in the number of eggs or meat produced, but the taste may become a crucial factor in accepting the quality of the product. Apparently the local poultry breeders have been consciously or unconsciously selecting for certain taste in their products over the years. If this is the case, it is probably safe to assume that the local consumer became adapted to a particular taste in these products. Unfortunately, most breeding experiments concentrate primarily on the quantitative increase and do not take into account the taste of the product.

In the present study, it has been noticed that under the same conditions, the Fayoumi crosses were not only better adapted to the local disease, feeding, and management conditions than the standard breeds, but their eggs and meat were accepted as equal to that of the Fayoumi in taste.

Summary and Conclusion

In a breeding program intended to increase egg production of the Egyptian Fayoumi chickens, Fayoumi, White Leghorn, Rhode Island Red and Barred Plymouth Rock breeds were crossed in all possible combinations and compared with the pure-breds. In the first year egg record, the Fayoumi crosses were slightly but insignificantly higher than the standard bred crosses. They were also higher than that of the Fayoumi alone and the standard breeds as a group. The difference in both cases was highly significant. Among all twelve cross combinations, the cross between Fayoumi sires and Barred Plymouth Rock dams proved the best. Within the standard bred crosses, the cross between the White Leghorn and the Rhode Island Red was the highest. Data from these twelve crosses indicate that whenever the sire was from a higher laying breed than the dam, the resulting cross-bred pullets laid more eggs than the reciprocal cross. Such a difference may be attributed to certain sex-linked genes that are involved in the inheritance of egg number. Spring hatched pullets were inferior to fall hatched ones and the difference in all cases was highly significant. Fayoumi crosses seemed better adapted to local conditions than the standard breeds or their crosses. The local consumer seems to prefer the taste of eggs and meat of Fayoumi and its crosses to that of the standard breeds and their crosses.

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PRECIPITATION IN ILLINOIS 1860 - 1970

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ABSTRACT.—Precipitation records of 110 years in Illinois were analyzed and discussed in relation to tornadoes, hail, sleet, snow, wet cycles, droughts, thunderstorms, industry, agriculture, topography, and pollution.

Ever since man appeared on this planet, water has meant "life" for him. He soon learned that the plants he ate, the animals he hunted, and the sanitation he needed depended upon precipitation.

It was not unusual for the American Indian to have his medicine man vainly attempt to regulate this unchained goddess through ceremonial dances and sacrifices. He would beat on drums to imitate thunder, throw firebrands in the air to simulate lightning, and blow mouthfuls of water into the air like rain or mist as an example for the heavens to do the same.

"Praying for rain" is an idea firmly rooted in our culture and language. Men prayed to the dead and then to the gods for rain. Some men still do so, just as some still stage rain dances that are combined magico-religious rites. The rain god was an important figure and Jupiter-Pluvius reigned among the supreme.

Today our major cities are facing a greater water crisis than ever before. The high standard of living we are accustomed to and our ever-increasing population are making demands on our water supplies never before anticipated. To modern man, water not only means "life," it means his very survival.

EARLY MEASUREMENTS IN ILLINOIS

The first rain measurements were taken about the time the first bowls or vessels were left exposed to the elements, intentionally or otherwise. Mention is made of rain measurements in India as early as 400 B.C., and the Masenah, a collection of religious writings of the first century, tells of recorded measures of rainfall in Palestine during the first century of our era. These are the first quantitative observations of precipitation now in existence.

Early precipitation measurements in Illinois were crude and unreliable in many parts of the state, especially in the small rural towns where the interested person was selected for the tedious job of daily weather recording. Reliable and dependable recorders were rare and had little responsibility for accuracy and dependability.

Gradually, as small farm communities grew into organized communities, the U.S. government post office became the local weather station. Reliability and accuracy improved under government control and regulations, so that by the mid-19th century dependable weather readings were being compiled. The number of first-order stations were increasing throughout the state, with even more second-order stations in more isolated regions.

The need was not great. Much of the state was rural and its needs were limited to the farmers' needs for crop growth and harvest conditions, and — of primary concern — the last and first-frost expectancy. Droughts and floods were of natural interest since either could mean the difference between success and failure, even life and death, for an entire community.

Communities began to realize the importance of weather stations, since weather data over a period of years was helpful in weather forecasting. Growing season days for corn and other crops was of importance to rural Illinois, for only through past weather records were they able to forecast probable frost expectancies. A record of hail and sleet storms would give the farmer a better chance to prepare himself financially against such losses — thus the "Illinois Weather and Crop Bulletin" prepared jointly by the Illinois and U.S. Departments of Agriculture with the assistance of the ESSA Weather Bureau, which is published today to fill these very needs.

Records of precipitation for Chicago before 1867 were scant except for Hazen, who in his published "Climate of Chicago 1893" estimated precipitation for the city as far back as 1843, with figures obtained by interpolation. But in 1867 a series of observations were begun under the direction of the Smithsonian Institution and continued until establishment in 1870 of the local Weather Bureau Office, which then became custodian of official records.

G. J. Symon devoted a large part of his life to measuring rain and helped establish many precedents that are still practiced. He organized a large group of voluntary observers in England to furnish rainfall observations for the British Isles. He also was instrumental in instigating carefully controlled experiments on the construction, exposure, form, and operation of rain gages. The storm gage was constructed in 1868 and the float gage was revised in 1870.

The Thomas overflow gage was developed in 1904 for the sole purpose of obtaining excessive rainfalls. Several other gages were developed for maximum catch — the 1914 Beard Gimbal hung rotating gage and the 1945 Moore rotating maximum catch gage. The Stewart 3-inch gage, 1940, and the standard 18-inch rain gage have been the standard gages used by the U.S. Weather Bureau. Other inventors, like Frank W. Larson, Thomas J. Johnson, and the inventor of the German standard Hellmann rain gage, contributed to the development of our modern-day gages.

By 1918-27 the U.S. Weather Bureau Climatological network consisted of approximately 90 gages, and this had increased to 110 by 1937. More rapid increases in gage density followed and by 1942 there were 160 gages throughout Illinois. There were 250 by 1948 and 280 by 1957. Our present network of first order substation observers and the use of radar for precipitation measurement have given man an unexcelled opportunity to better understand his climatological environment.

The need for adequate instruments to calibrate radar for precipitation measurements pointed out the primitiveness of present-day rain gage. Thus, future rain gages may well be radar instruments since radar measures rainfall more accurately than a fairly dense climatological network of one rain gage per 200 square miles.

Basically the use of rain gages falls into three categories: nonrecording gages for climatological use, self-recording and totalizers for hydrology, and the calibration-type rain gage that accurately portrays rates of rainfall and accounts for cloud physics and radar studies.

Nonrecording Gage

The standard gage used for years around determination of precipitation on a climatological basis by various countries to measure rain and snow was considered of secondary importance.

The height of the rim above the funnel varies from 1 to 3 inches. Angle of inclination of the funnel

with vertical walls is also variable, ranging from 45° for New Zealand to 20° for Croatia. The rim should be designed to (1) provide a sharply defined orifice of substantial metal that will not be easily bent; (2) provide a rim high enough to prevent splashing out of the gage; (3) provide a steep enough funnel to bring the water smartly into the receiver and reduce splashout; (4) provide a minimum wetting surface; and (5) have a hole small enough to retard evaporation but not be easily clogged. Shielding of standard gages against wind losses has not generally been accepted because of additional costs.

Holding of precipitation after it has been caught is a principal cause of loss through evaporation. In warm climates, placing the gage into the ground or shade or painting the outside white will keep it cooler and reduce evaporation loss.

Measurement of rainfall can be done in three ways:

1. Weighing the catch — This method involves emptying the contents of the gage into a container of a known weight, then weighing and converting to inches of rain by a suitable table.
2. Use of a graduated measuring glass — This method is most commonly used in foreign countries with a bottle as a receiver and its contents transferred to an accurately graduated measuring glass.
3. Use of a measuring stick — This is the American method and is simple and direct. A graduated stick is used to measure the depth of water in a receiver. The graduations on the stick are calibrated to read in inches of rainfall.

Purpose and Scope of Study

The purpose of this study is to gain a better understanding of Illinois precipitation. It is pertinent to observe the past, as well as present and future trends. Has man's activities changed precipitation? If so, how and why is it changing? By investigating the precipitation (rainfall, snowfall, hail, and sleet) for Illinois, one is able to understand weather phenomena such as droughts, wet cycles, tornadoes, thunderstorms, hail and sleet storms. Distribution of precipitation throughout the state was interpreted in relation to industrial and agricultural needs, as were the reasons why precipitation is greater in one geographic location than in another.

Storms

The seasons of maximum cloudiness and storminess are during winter and spring. During the summer, the storm systems tend to be weaker and stay farther north, leaving Illinois with sunshine and intermediate thunderstorm activity of short duration. The fall months are associated with variable warm, dry periods, ending quickly with the return of storminess in November.

Precipitation during fall, winter, and spring falls uniformly over large areas, while summer showers are brief and erratic, affecting relatively small areas with uneven distribution. These summer thunderstorms often tend to be heavy, with hail and destructive winds, causing local flooding followed by runoff and soil erosion plus tornadoes and lightning.

Thunderstorms

The average annual distribution of thunderstorms in Illinois has a maximum of 50 to 60 days in western and southern Illinois with lowest frequencies of less than 40 days in northeastern Illinois. Table 1 is a summary with the mean annual number of days of thunderstorm activity reported in state divisions. Thunderstorms produce between 38

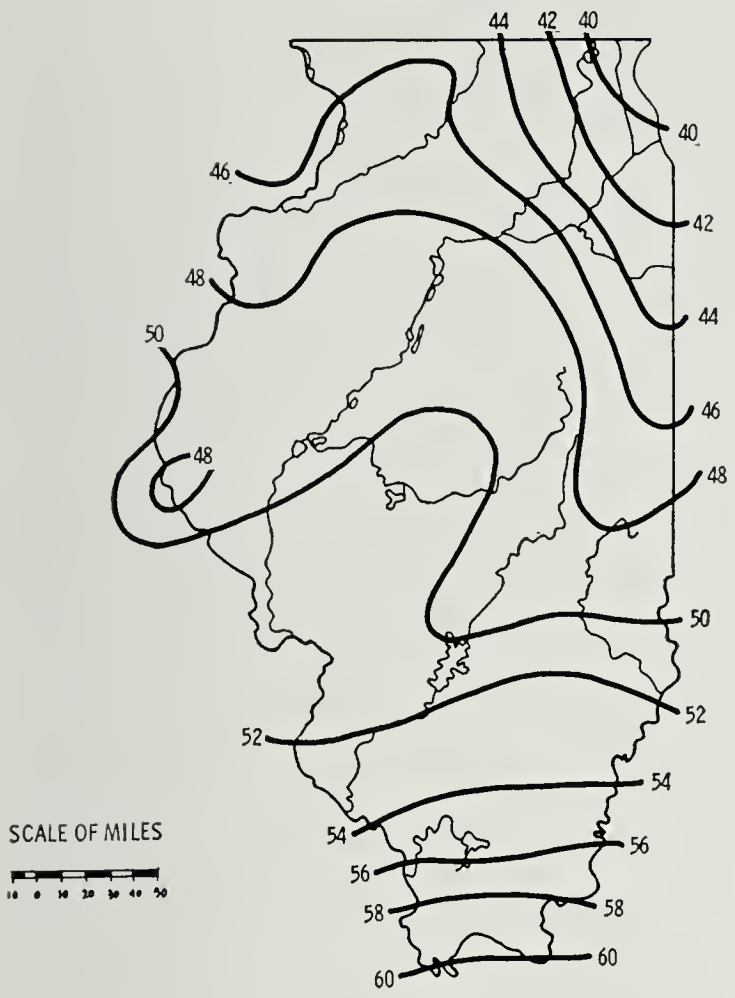
percent and 45 percent of the average annual precipitation for Illinois with diurnal distribution occurrences in the winter months between 6 A.M. and 2 P.M. In spring (March-May) diurnal distribution is at a minimum from 10 A.M. to 12 P.M. The summer (June-August) thunderstorm minimum also is in the 10 A.M. to 12 P.M. period while the maximum is between 2 A.M. and 4 A.M. In the fall (September-November) midday minimums occur at all locations with maximum occurrence in the 8 P.M. to 10 P.M. period as well as the midnight to 2 A.M. hours. Thus the annual diurnal thunderstorm distribution minimum occurs in the 10 A.M. to 12 P.M. period and double maximum in the nocturnal hours. In northern and central Illinois the first maximum ends at 10 P.M. while in southern Illinois it ends at 8 P.M. The second maximum throughout the state occurs between midnight and 4 A.M.

The average seasonal and monthly frequencies of days and hours with thunderstorms reveal that June and July are the peak months throughout Illinois with the longest durations in April-July and the shortest in the winter. During the 1950-1970 period the average long-term thunderstorm averages indicated that this period was below normal for thunderstorm frequencies. Figure 1 shows the annual thunderstorm frequency for the state of Illinois. You can see how the frequency of thunderstorms increases through the Shawnee Hills section and drops off rapidly to the north. The high frequency in the Rock River Hills sector drops off rapidly to the east to the minimum of 40 in the northeast corner of the state.

TABLE 1.—Illinois Climatic Summary.

PRECIPITATION IN INCHES	YRS.	NW	NE	W	C	E	WSW	ESE	SW	SE
Mean Annual	30	34.25	33.27	35.85	35.04	35.57	36.26	39.94	43.26	43.27
Maximum Annual and Year	38	46.38 1965	41.49 1965	46.85 1965	45.56 1965	43.93 1965	47.39 1945	55.46 1957	60.45 1945	66.83 1950
Minimum Annual and Year	38	26.47 1963	23.93 1956	25.28 1953	25.58 1963	24.12 1693	24.94 1953	28.19 1953	28.00 1953	29.19 1936
Max. Monthly Average Month & Year	38	10.05 9/61	11.55 9/61	11.92 10/41	10.72 9/61	10.08 5/43	10.88 5/43	11.86 5/43	12.96 8/46	14.04 1/50
Min. Monthly Average Month & Year	38	.05 10/64	.15 10/64	.15 10/64	.09 10/64	.17 2/47	.11 2/47	.11 2/47	.21 10/64	10/64 .11 2/47
Mean Precipitation Season October - April	30	15.22	15.75	16.43	17.20	17.64	18.18	21.17	23.93	24.60
Mean Annual Number of Days with 10" or More	38	66	66	67	67	67	67	71	70	71
Mean Annual Number of Days With Thunderstorms	25	45	40	50	48	44	50	47	52	49
Mean Annual Snowfall	30	29.4	28.6	23.4	22.1	21.6	16.5	15.6	11.6	11.1

FIG. 1 ANNUAL THUNDERSTORM FREQUENCY



Sleet

Central Illinois has the highest sleet frequency with a six to seven-day occurrence per year, whereas points in northern and southern Illinois average five or six days of sleet. Regional variations exist in the diurnal distribution of sleet. In southern Illinois sleet is most common in the afternoon and relatively uncommon in the morning. In the state's central areas, sleet is most common in the late afternoon, early evening, and early morning. In the northern part of the state, the mid-morning is the most frequent period for sleet and the late afternoon the least frequent. Table 2 illustrates the number of occurrences of sleet per 2-hour periods for the northwestern, central, and southeastern sectors of the state. Comparisons can be made during January, February, and March and the hours of termination.

Hail Storms

Of all weather phenomena, only hail has a short-duration, never more than 20 minutes and an average of only 7 minutes. In an average year, the number of hail days at any one station in Illinois varies from one to four. Hail is most frequent in the Springfield Plain area. Other regions with relatively high average frequencies are the Shawnee Hills of southern Illinois, the Rock River Hill country, and the Wisconsin Driftless Section in the northwestern part of the state. Areas experiencing the lowest number of hail days in an average year include a portion of the Galesburg Plain west of the Illinois River Valley and most of eastern Illinois.

The number of hail days varies

Table 2.—Number of occurrences of sleet per two-hour periods.

ENDING HOURS (CST)	JANUARY			FEBRUARY			MARCH			TOTALS		
	NW	C	SE	NW	C	SE	NW	C	SE	NW	C	SE
0200	3	6	5	3	0	0	0	1	2	10	8	11
0400	1	6	2	3	1	1	1	1	0	8	10	3
0600	2	4	3	3	3	1	0	4	0	7	14	4
0800	6	2	0	10	1	0	0	4	1	17	8	1
1000	5	3	4	7	2	2	1	1	3	15	9	9
1200	1	2	6	2	2	2	4	4	1	9	11	7
1400	1	2	8	0	2	0	4	1	0	8	7	13
1600	1	1	6	1	3	1	3	0	3	6	6	14
1800	3	4	4	1	3	1	1	4	1	7	15	12
2000	2	0	3	0	7	2	3	4	0	7	13	7
2200	2	2	2	4	5	4	5	2	2	11	10	12
2400	2	7	4	4	1	0	4	1	2	10	10	10
TOTAL	29	39	47	38	30	14	26	27	15	115	121	103

considerably from year to year and decade to decade, with as many as fourteen days of hail in a single year at one station and no hail days over much of the state. Usually, though, about 90 percent of the state experiences at least one day of hail in an average year. Eighty percent of hail days occur between March and August, and mostly in the spring, from March through May. The minimum is reached in winter, with a gradual decrease through summer and fall.

Tornadoes

Tornadoes are the most violent of all storms, but their narrow, short, and random paths lessen their danger. In the early 1950's the Weather Bureau's efforts in making the public aware of tornadoes and their typical forms for rapid reporting and re-

Table 3.—A half century of tornadoes.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1956-65 (10 yrs.)	0	10	28	52	41	37	14	19	29	3	8	21	262
Tornado Days	0	4	12	28	21	25	8	16	11	3	2	2	132
Deaths	0	6	1	11	0	1	0	0	2	1	2	15	39
1916-55 (40 yrs.)	4	0	46	32	46	21	10	12	8	8	12	8	207
Tornado Days	3	0	22	19	28	19	10	9	6	4	5	4	129
Deaths	2	0	714	33	140	7	1	0	22	1	0	2	922
1965 Tornadoes	0	1	0	9	3	1	0	2	4	0	8	0	28
Tornado Days	0	1	0	3	1	1	0	2	2	0	2	0	12
Deaths	0	0	0	6	0	0	0	0	0	0	2	0	8
1964 Tornadoes	0	0	3	4	0	0	0	0	0	0	0	0	7
Tornado Days	0	0	2	2	0	0	0	0	0	0	0	0	4
Deaths	0	0	0	0	0	0	0	0	0	0	0	0	0
1963 Tornadoes	0	0	1	8	0	2	0	0	1	0	0	0	12
Tornado Days	0	0	1	4	0	2	0	0	1	0	0	0	8
Deaths	0	0	0	2	0	0	0	0	0	0	0	0	2
1962 Tornadoes	0	0	1	1	5	2	1	0	0	0	0	0	10
Tornado Days	0	0	1	1	4	2	1	0	0	0	0	0	9
Deaths	0	0	0	0	0	0	0	0	0	0	0	0	0
1961 Tornadoes	0	0	9	2	3	3	6	2	9	0	0	0	34
Tornado Days	0	0	2	2	1	3	2	2	4	0	0	0	16
Deaths	0	0	1	0	0	0	0	0	1	0	0	0	2
1960 Tornadoes	0	3	2	7	11	14	1	1	0	0	0	0	39
Tornado Days	0	1	1	4	4	8	2*	1	0	0	0	0	21
Deaths	0	0	0	0	0	0	0	0	0	0	0	0	0
1959 Tornadoes	0	3	5	1	5	1	3	3	14	2	0	0	37
Tornado Days	0	1	3	1	4	1	2	3	3	2	0	0	20
Deaths	0	0	0	0	0	0	0	0	1	0	0	0	1
1958 Tornadoes	0	0	0	4	6	7	3	5	0	1	0	0	26
Tornado Days	0	0	0	1	2	4	2	3	0	1	0	0	13
Deaths	0	0	0	1	0	0	0	0	0	1	0	0	2
1957 Tornadoes	0	0	5	4	6	5	0	0	0	0	0	21	41
Tornado Days	0	0	1	4	3	2	0	0	0	0	0	2	12
Deaths	0	0	0	0	0	1	0	0	0	0	0	15	16
1956 Tornadoes	0	3	2	12	2	2	6	1	0	0	0	0	26
Tornado Days	0	1	1	6	2	2	5	1	0	0	0	0	18
Deaths	0	6	0	2	0	0	0	0	0	0	0	0	8

*Single Tornado continued past midnight.

liable recognition has resulted in more sightings. Approaching storms may bring harmless but ominous-looking clouds which a frightened populace will mistakenly report as a tornado.

Tornadoes are most frequently associated with thunderstorms, which can move along a path of a hundred miles or more. Nine U.S. tornadoes during the last fifty years covered paths of 200 miles or more. Three of these touched Illinois. The Mattoon-Charleston tornado of May 26, 1917, had the longest officially reported path — 293 miles. The killer Tri-State tornado of March 18, 1925, had a 219-mile path, mostly in the Murphysboro and West Frankfort area. On April 17, 1922, a less fatal tornado traversed 210 miles in Illinois, Indiana, and Ohio. Most tornado paths have an average range of about 15 miles.

Illinois tornadoes can hit any hour of the day or night, but 75 percent of them have occurred between noon and midnight, about 65 percent between 2 and 8 P.M. and nearly 50 percent between 3 and 7 P.M. Less than 50 percent occurred between 6 A.M. and noon.

Most tornadoes occur during the months of March, April, May, and June, with April and May the peak months. But no months can claim total immunity. Table 3 shows a half century of tornadoes from 1916 through 1965, when they occurred, and the number of deaths.

The mathematical probability that a specific location will be struck by a tornado in any one year is small, but statistics seem meaningless when one considers an 1888 tornado that killed 18 people in Mt. Vernon. Then on December 18, 1957, two tornadoes just 35 minutes apart again struck

TABLE 4.—Counties with the fewest number of tornadoes.

One Since 1916	
Scott	4-24-61
Harden	6-10-59
Two Tornadoes	
Bond	12-2-50, 2-5-60
Calhoun	4-19-27, 5-31-58
Menard	3-26-48, 3-12-54
Three Tornadoes	
Pope	5-12-18, 3-2-40, 4-30-40
Johnson	3-2-40, one death, 4-30-40, 12-18-57
Williamson	3-18-25, seven deaths, 5-9-27, 12-18-57
Jo Davies	5-16-56, 7-9-66, 6-11-67
Stephenson	6-22-44, 10-8-58, 4-17-57
Kendall	5-26-17, 8-15-58, 9-26-59
Cumberland	2-9-60, 3-6-61, 6-13-63
Schuyler	5-9-27, one death, 3-30-38, 3-14-57
Case	12-3-55, 6-10-57, 6-23-60
Henderson	4-18-63, 4-22-63, 1-24-67
Tutnam	8-29-28, 11-26-65, 4-21-67

COUNTIES WITH THE GREATEST NUMBER OF TORNADOES

Madison	16 tornadoes, 22 deaths
Randolph	17 tornadoes, 1 death
St. Clair	16 tornadoes, 16 deaths
Vermillion	17 tornadoes, 7 deaths
Macoupin	18 tornadoes, 5 deaths
Highest Number	
Champaign	21 tornadoes, 7 deaths
Cook	21 tornadoes, 55 deaths

Mt. Vernon. Every county in the state has experienced at least one tornado in the past fifty years, but the northwest and southeast portions of the state were most immune. The highest frequency of tornadoes occurs in an area approximately 50 miles from St. Louis and extends northeast to the northern suburbs of Chicago, with a southern line extending northeast to Danville.

In recent years Illinois' northern counties have had the greatest number of tornadoes while the southern half of the state has had the least.

The highest tornado death toll in Illinois was recorded on March 18, 1925, when 606 persons were killed in the Murphysboro and West Frankfort area between 1 and 4 P.M. On May 26, 1917, 106 persons were killed in the Mattoon-Charleston area at 3:26 P.M. On June 4, 1877, 16 lives were lost in a tornado which hit Mt. Carmel at 4:30 P.M. And on May 18, 1898, the Carroll-Ogle area recorded 16 deaths due to tornadoes.

On April 21, 1967, Belvidere experienced a severe tornado killing 24 persons between the hours of 3:50 and 4:25 P.M. On the same day, three lives were lost in between 5:24 and 5:39 P.M. Fifty-nine tornado deaths were reported in 1967, when 17 of the 40 tornadoes occurred in April, eight in January, five in June, three in May and December, and one each in March, July, August, and October (Table 4).

It is important to remember in observing where tornadoes occur the greater the county area, the greater the frequency of tornadoes. In other words, the more square miles there are in a county, the greater the chance of a tornado developing within its borders. Also, the heaviest occurrence of tornadoes is through the south central and north central section of the state, running in a southwest to northeast diagonal, and with Cook, Kane, and Will Counties in the north; Champaign and Vermillion Counties in the central state and Macoupin, St. Clair, and Randolph Counties in the southwestern section.

Droughts

A record of drought periods of varying durations were obtained from 1906-1955 data. These are recorded as 1908-1909, 1914-1915, 1931-1934, 1940-1941, and 1953-1954. All droughts are classified as to statewide severity and ranked according to severity, with durations of 3, 6, 12, 24, 36, 48, and 60-month periods.

The frequency of droughts for periods of 3 to 60 months in relation to severity is greatest in the southeastern, extreme southern and southwestern regions of the state. Normally, the severity of droughts decreases with the larger dry periods. One of the worst droughts in Illinois history from the standpoint of severity and extent occurred in the 1930's.

The regions of Illinois that are most susceptible to drought are elongated and oriented in a SW-NE axis, with shorter droughts in a NW-SE axis. The NS axis is usually found in droughts of 36 months and longer.

There is always a 50 percent chance of another drought somewhere in Illinois about 30 months after the first one. But the state enjoyed a major drought-free period from 1943 through 1951.

In northern Illinois very low readings were recorded in the years 1956 and 1957. Antioch recorded 22.35", Aurora 22.09", Chicago 21.19", Freeport 27.49", Elgin 22.17", Morris 22.30", Minonk 21.54", LaSalle 18.91", Galena 25.35", Galva 23.13", Joliet 25.74", Kankakee 25.18", Ottawa 22.06", PawPaw 24.93", Pontiac 22.94", Wheaton 23.44", Walnut 24.86", Tiskiliva 19.36", Streator 22.08", and Sycamore 22.08". Read-

ings in 1901 were 17.31" at Mt. Carroll, 19.33" at Aledo, 22.56" at Walnut, 25.52" at LaGrange, 22.21" at Aurora, and 20.11" at Ashton. Other stations experiencing minimums in that same northern region were Galesburg with 18.80", Marengo with 19.70", Galena with 20.44", Sycamore with 21.35", and Winnebago with 24.43".

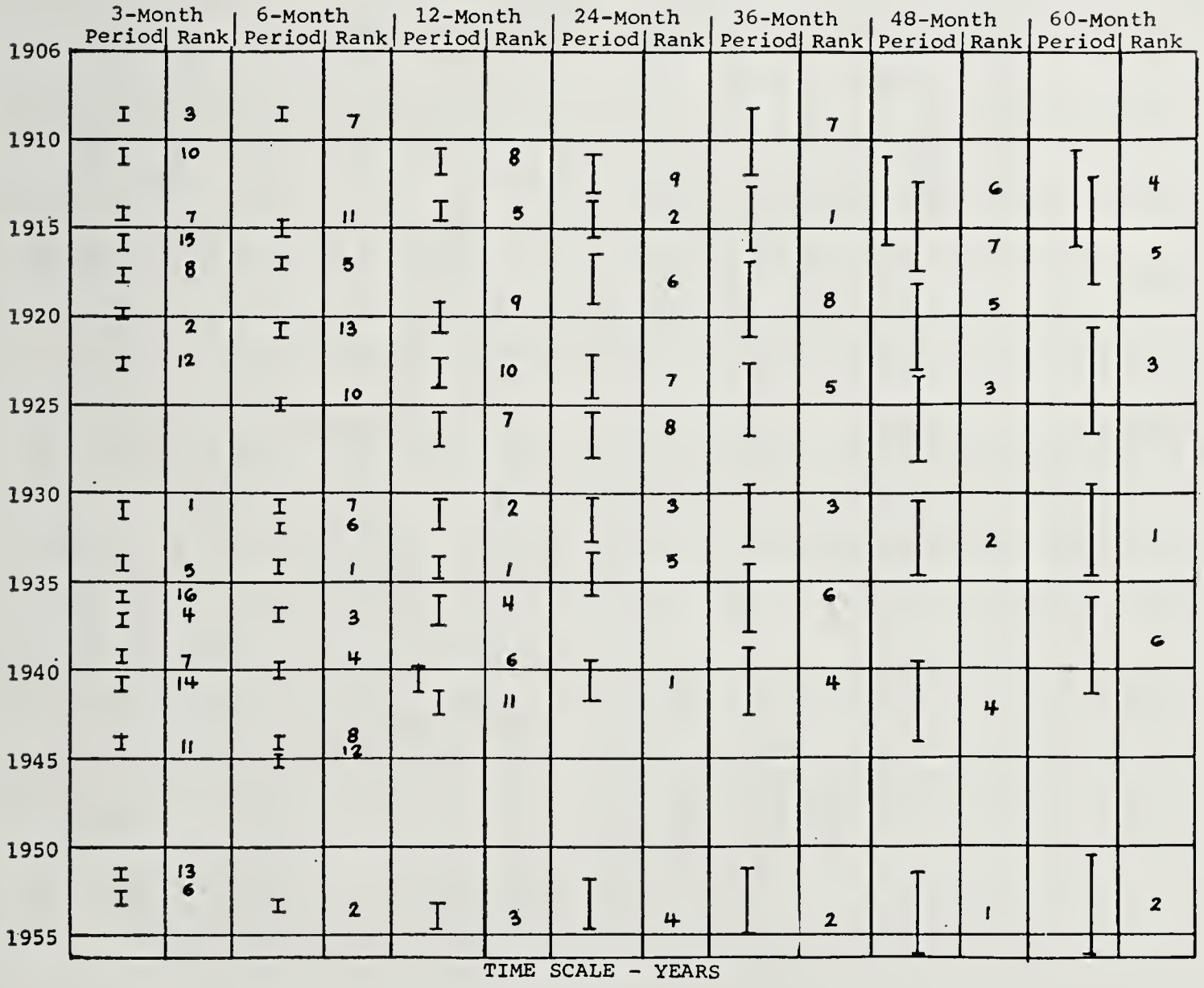
In central Illinois, not as many low readings were recorded during these years, with Athens recording 25.12", Bloomington 26.24", Golden 21.19", Hoopeston 27.82", Macomb 26.73", LaHarpe 24.22", Roberts 26.52", Watseka 29.80". All recordings had a ten-year minimum.

A ten-year (1950 to 1960) minimum precipitation was reached in 1953 for southern Illinois with the following readings, 30.04" Albion, 30.88" Anna, 24.82" Benton, 33.83" Cairo, 23.90" Carlyle, 30.15" Carbondale, 26.00" Centralia, 27" Carmi, 24" Chester, 26.32" Duquoin, 28.18" Edwardsville, 28" Flora, 29.68" Golconda, 25.04" Greenville, 31.62" Harrisburg, 27.57" McLeansboro, 30.80" Shawneetown, 23.32" Sparta, and Waterloo 20.04".

Wet Periods

Southern Illinois had ten-year average maximum readings of 60.40" at Albion, 63.86" at Anna, 72.98" at Cairo, 57.82" at Carbondale, 53.68" at Carmi, 54.26" at Chester, 61.09" at Fairfield, 60.39" at Flora, 55.84" at McLeansboro, 60.36" at Mt. Carmel, 61.14" at Salem, 67.45" at Shaw-

Table 5.—TIME SCALE FOR PEAK PERIOD OF DROUGHTS



neetown, 54.51" at Sparta, and 50.49" at Waterloo.

In northern Illinois, 1954 was a wet year with these ten-year maximum precipitation readings: Joliet 44.69", Monmouth 40.31", Antioch 42.71", Aurora 47.03", Chicago 45.71", Elgin 42.41", Streator 39.50", Rochelle 41.02", Tiskilwa 43.78", and Wheaton 45.58".

In 1945, one in every three southern stations recorded maximum precipitation. Only about one to five northern stations experienced minimum precipitation during the same period.

In 1902, northern Illinois experienced one of its wettest years in a century with average maximum annual precipitation totals of 53.37" at Streator, 48.73" at Walnut, 51.68" at Tiskilwa, 48.89" at Dixon, 56.11" at Joliet, 53.09" at Monmouth, 49.97" at LaSalle, 51.54" at Mt. Carmel. The year before, some of these same stations experienced some of their driest years.

In summary, regions of heavy precipitation have corresponding regions of dryness throughout the state. This is also true in reverse, with drought conditions in southern counties and wet conditions in northern counties. A similar situation presents itself with reversals of extreme precipitation from one year to the next.

The reason for these reversals in yearly precipitation and area droughts is difficult to explain, but the condition seems to exist in all phases of weather phenomena. Eventually they do seem to balance off.

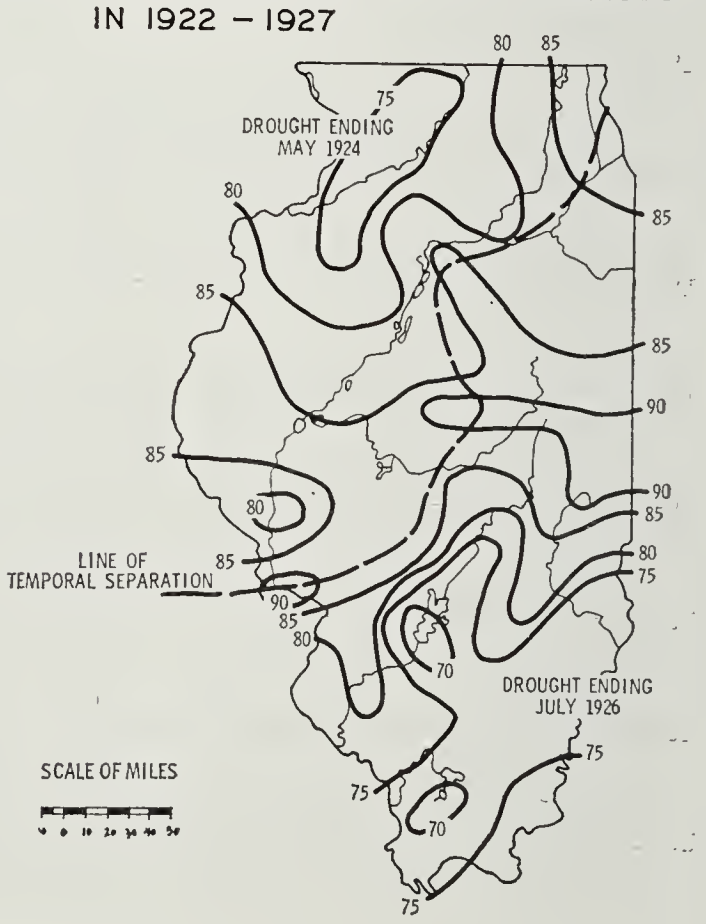
Figure 2 geographically shows the ending dates of the driest 24-month periods in 1922-1927. Table 5 illustrates the time scale for peak periods of droughts from 1906-1955 and their rankings in relation to their durations.

Snow

The average annual snowfall ranges from 30" in the north to 10" in the extreme south. Ninety percent of Cairo's seasonal snowfall ranges from 10" to 68" but Cairo has had 48" of snow in one winter and none in another winter. One-third of Cairo's winters have recorded less than 5" of snow. Snow cover in northern Illinois is 50 days annual average, as against only about 15 days in the south. Table 6 illustrates the average monthly and annual snowfall by divisions from 1931-1960. Monthly totals indicate which months receive the maximum snowfall and which receive the minimum.

Heavy snows, 4" to 6" or more, average one or two per year in northern areas and less frequently in the south, while the statewide winter snowfall has averaged approximately 21.5" for the seasons before the turn of the century up to the present. Thirty-seven winters have had that amount or more; 39 have had less. Eleven winters out of 76, which had an average snowfall of more than 30" are considered winters of "heavy snow." Four such winters occurred from 1900-1930. But the average

FIG.2 ISOPERCENTILE PATTERN & ENDING DATES OF DRIEST 24 MO. PERIODS IN 1922 – 1927



snowfall from 1930-1950 was only 18.2" and no winter produced as much as 29". Our winters seem to follow a consistent pattern with heavy snow one season and light snow the next (Table 7). For example, in the winter of 1910 Illinois had less than 20" of snow. In contrast, the next season's snowfall was totaled over 40". Again, in 1912 we had less than 20" while the next winter recorded approximately 27".

Winters having approximately the same snowfall for two consecutive seasons have been few during this century. They were the winters of 1914 and 1915, 1920 and 1921, 1936 and 1937, 1950 and 1951. The record for the least snow during the three winter months was established in the months of December 1930, through February 1931, with a state average of only 5.1". The most significant continuous snow shortage extended through three winters, 1920-1923, with an average of less than 12" for the period.

TABLE 6.—Average monthly & annual snowfall by climatological divisions 1931-60.

	NW	NE	W	C	E	WSW	ESE	SW	SE	Average Monthly Illinois Snowfall
January	7.6	7.2	6.0	5.2	4.6	3.7	3.2	2.9	2.6	4.8
February	5.7	6.1	4.8	4.8	4.9	3.5	3.3	2.8	3.0	4.3
March	6.2	5.3	5.3	4.6	4.1	3.8	3.7	2.6	2.3	4.2
April	0.7	0.8	0.8	0.5	0.5	0.2	0.2	0.1	0.1	0.4
November	2.1	2.3	1.4	2.0	2.5	1.5	1.5	1.0	0.8	1.7
December	7.1	6.9	5.1	5.0	5.0	3.8	3.7	2.2	2.3	4.6
1931-1960 30 yr. Ave.	29.4	28.6	23.4	22.1	21.6	16.5	15.6	11.6	11.1	20.0
1956-1965 10 yr. Ave.	32.6	33.1	29.0	27.2	25.6	22.0	20.9	14.3	14.6	24.4
1961-1965 5 yr. Ave.	33.4	35.2	29.9	27.5	27.3	23.7	23.8	13.7	15.9	25.4

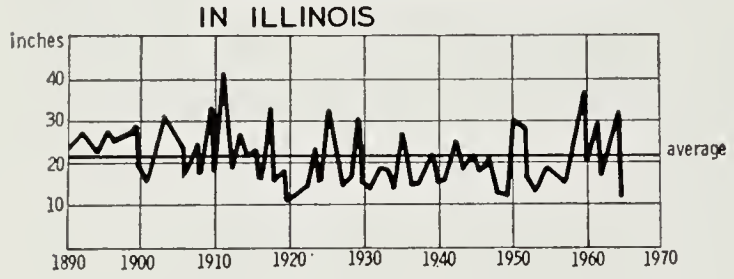
TABLE 7.—Average monthly snowfall & extremes in inches for winters of 30 inches or more.

WINTER	OCT	NOV	DEC	JAN	FEB	MAR	APR	SEASON
1911-12		2.3	4.0	7.3	12.0	14.8	2.2	42.6
1959-60		3.4	2.9	3.3	12.4	17.3		39.3
1964-65		2.1	5.0	6.7	8.4	11.8		34.0
1917-18	0.8	0.3	9.9	20.8	2.0	0.2		34.0
1909-10		0.3	14.9	5.8	8.4		3.9	33.3
1925-26	2.3	3.2	3.1	5.7	3.3	9.9	5.0	32.5
1961-62		1.2	9.0	10.6	8.5	2.4	0.7	32.4
1903-04		1.3	6.5	11.6	6.0	5.0	1.6	32.0
1950-51		3.1	9.8	5.5	5.0	7.1	1.4	31.9
1929-30	1.9	1.4	9.5	12.1	1.4	5.2		31.5
1951-52		7.9	11.6	3.3	3.3	5.2	0.1	31.4

EXTREME FEBRUARY AVERAGE = 14.7 INCHES IN 1900

The relatively snow-free winter of 1965-1966 was again an example of little one year and heavy the next, with the record snowfall for Chicago in the winter of 1967. Figure 3 shows graphically the great diversity and fluctuations in snowfalls throughout the years that they have been recorded in Illinois. In conclusion, when considering trends and analogies, it is rather difficult to discern any definite trend (Figure 3), although there seem to be slight 20-year cycles of above-average snowfalls from 1900 to 1920 and below-average snowfalls from 1930 to 1950.

FIG. 3 AVERAGE WINTER SNOWFALL IN ILLINOIS



Pollution Effects on Illinois Precipitation

It has long been theorized that pollution of the atmosphere, through distribution of smoke, foreign particles, and gases, has contributed to precipitation changes.

There have been several studies in reference to these claims, especially in down wind localities of St. Louis, Champaign-Urbana, Peoria, Decatur, and LaPorte, Indiana. Many of these studies have ended inconclusively; others have indicated definite trends. Falconer and Vonnegut (1948) and Stout (1962) have reported that industrial effects may increase precipitation, and Landeberg (1956) has noted that large urban areas produce 5 to 15 percent increases in precipitation, frequencies of rainy days, and number of thunderstorm days. LaPorte, Indiana has recorded a 30 to 40 percent increase in precipitation and other related conditions since 1925, and the change compares favorably with the production curve of the Chicago steel industrial complex 30 miles west.

A ten-year study of precipitation records from gages throughout the Champaign-Urbana area indicate the average annual precipitation over the central part of these cities is five inches greater than the precipitation recorded on the western edge of Champaign. The major industrial complexes throughout the state produce great quantities of heat, moisture, condensation, and freezing nuclei conducive to sizable increases in precipitation.

A careful assessment of all available climatological data indicates that these sizable increases were real, not fictional, as related to micro-climatic conditions; however, the same cannot be said about the general statewide climate. Here there seem little if any consistent changes or trends to warrant any concern. Smoke and haze records indicate little increase until the early 1940's, and even then, the only definite effects have been local, not statewide (Figure 4). Of course, one of the major problems when assessing climatic changes is the percentage of error by the recorder and the short-time duration in official precipitation records.

Today, with the great interest in the effects of pollution on our environment, it is easy to make quick conclusions and assumptions. Atmospheric pollution has always been with us, not through man's involvement but in much greater degree through huge volcanic eruptions. Today we have definite proof that microclimatically man's pollution of his cities does affect the down-wind localities in direct proportion to the amount of pollutants in the air. If man continues to pollute his atmosphere at the same rate, it stands to reason that there will be major worldwide climatic changes that will have

a drastic influence on man's very survival.

Figure 5 geographically indicates some abnormalities in local microclimatic areas of the state, especially noticeable around industrial complexes.

Topographic Effects on Precipitation

Illinois encompasses approximately 56,000 square miles, is centered near 40° north latitude and 89° west longitude, has a humid continental climate, and is located within a major thunderstorm region. The state is relatively flat except for the Shawnee Hills area in the extreme southern sector and the Rock River Hill country in northwestern Illinois.

The mean elevation above sea level

FIG. 4 ANNUAL NUMBER OF DAYS WITH SMOKE-HAZE CONDITIONS 3YR. AVE.

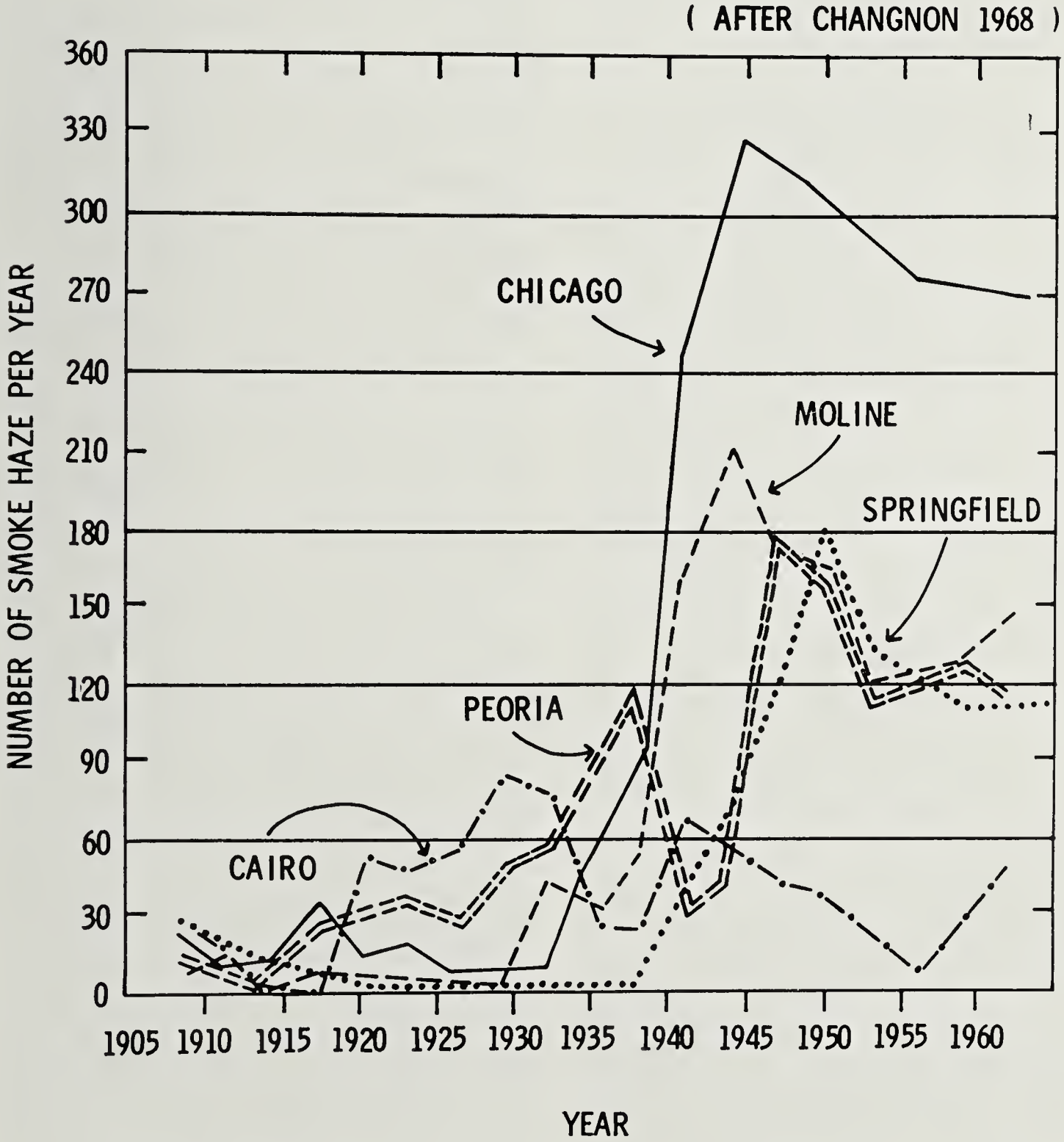
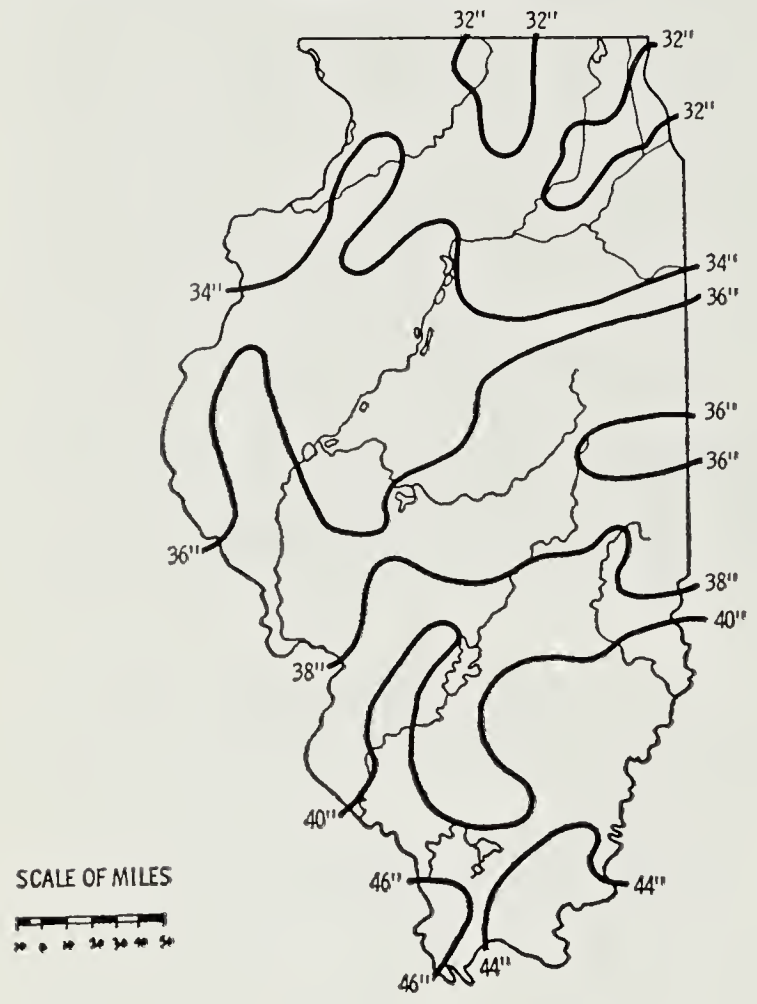


FIG. 5 1860 - 1930 AVE. MEAN PRECIPITATION



is 60 ft. and elevation varies from a low of 260 ft. in the south to a high of 1240 ft. in the northwest. The annual rainfall varies during the warmer half-year from 20 to 24 inches and in the colder half from 12 to 23 inches. The driest month is February and the wettest month varies from March in the south to June in the north.

The mean annual precipitation ranges from 32.6" in the northern part of the state to 47.5" in the extreme south. This is principally due to latitude difference which control both temperature and precipitation since the Gulf of Mexico with its warm air-mass temperature and high-moisture content is the primary source of precipitation in the central to eastern half of the U.S. The annual precipitation is approximately one and one-half times as great in the extreme south as in the extreme north, but most of the excess in the southern portion falls during winter and early spring.

The mean precipitation map illustrates this fact with the isohyetal lines running basically from west to east in the extreme southern portion of the state and then begins running in a southwest to northeast axis just north of the Shawnee Hills sector. The topography of this region, with its higher elevations and rougher terrain, correlates very closely with greater precipitation in direct response to higher elevations. Precipitation falls off again to normal precipitation for its latitude just north of the Shawnee Hills region with an annual mean precipitation of 44 inches, the same as for the region south of the Shawnee Hills sector.

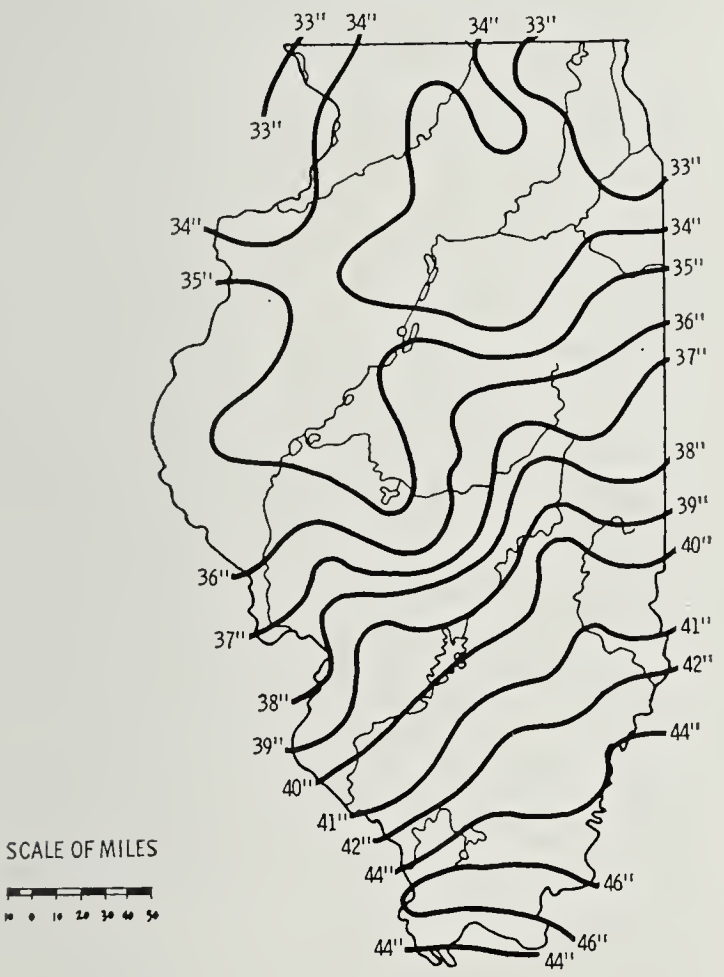
The 46" annual mean precipitation for the Shawnee Hills sector, plus greater thunderstorm and hail activity for this sector, seems to indicate definite topographical effects through greater turbulence and uplift of unstable air masses as they move north to northeast across the state.

There is a noticeable increase in thunderstorm and hail activity, as well, in the Rock River Hills region in northwestern Illinois. At this latitude the normal precipitation would average 32" to 33" instead of 34" to 35", which seems to be normal for the area. The isohyetal lines do not run in the normal southwest to northeast direction but almost in a north to south direction with the 35" annual mean precipitation running from about Grafton, Illinois, up to Keithsburg, some 115 miles to the north. This is probably due to the nearness of the thunderstorm centers in Missouri and Arkansas to the southwest and west of Illinois. The storm systems and weather fronts also move eastward and northeastward through the state, causing heavier amounts of rainfall from west to lighter amounts in the eastern tracks.

The Galena area receives an annual mean of 33" of precipitation that increases over the Rock Hills area to the west and then drops off

again from Marengo along a line to Gary, Indiana. Thus topography of these regions must be considered when considering the influential factors that might cause abnormal precipitation for specific locations. Figure 6 geographically illustrates these observations.

FIG. 6 MEAN ANNUAL PRECIPITATION (INCHES)



Precipitation and Land Use

Land use in relation to precipitation throughout the state is adequate in certain areas and inadequate in others. Most of Illinois industry is well developed and located near Lake Michigan or along the major rivers of the state. Few industries are restricted by the climate, but some are restricted by water supply. Adequate ground water for industrial and municipal uses is limited to a few locations. Large areas in the central and southern portions of Illinois depend on artificial reservoirs which in turn depend greatly upon climatic factors of precipitation, runoff, evaporation, evapotranspiration, silting, and erosion.

Precipitation throughout the state is remarkably regular, and it is unusual to have prolonged dry periods during the growing season. Generally speaking, the state is extremely well suited for corn, soybeans, wheat, hay, and oats, with sufficient precipitation for truck farming in northern Illinois and around Chicago and St. Louis. The normal precipitation for July and August is insufficient to meet the demands of a vigorous growing field crop, so sub-soil moisture must be stored during the previous fall and spring for best crop production. The 32" to 48" of precipitation favor a very high standard of agricultural production throughout the state.

On the whole, land use and precipitation are usually quite adequate thanks to Illinois' lack of severe extremes. When they do exist, the extremes balance one another off over the long-term cycles. Variability in the climate on a daily and seasonal basis does promote a vigorous and healthy populace.

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ADENOSINE TRIPHOSPHATE AND RADIATION-INDUCED CHROMOSOMAL ABERRATIONS IN *DROSOPHILA MELANOGASTER*

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ABSTRACT.—Adenosine triphosphate (5 mg/ml) injected into male *Drosophila melanogaster* which were mated daily for twelve days decreased the percentage of x-ray induced dominant lethals in broods assumed to represent immature spermatozoa and spermatids. In four out of the twelve broods, there was a significantly lower percentage of dominant lethals (determined by the failure of the eggs to hatch after 24 hours). However, if the ATP-injected males were irradiated in air and posttreated in nitrogen, dominant lethal frequency was reduced only in the brood presumed to represent spermatids at the time of irradiation. The injection of ATP prior to radiation into males that were irradiated in nitrogen and post-treated in nitrogen, reduced the percentage of dominant lethals in four broods (which represented spermatids and spermatogonia at the time of irradiation). When the males were injected with ATP, irradiated in nitrogen and then permitted to recover in air, the dominant lethals were reduced in two broods (late spermatids and spermatocytes) but increased in two other broods (early spermatids and cells in first meiotic division). The exogenous ATP injections did not reduce the frequency of radiation induced sex-linked recessive lethals or translocations between 2nd and 3rd chromosomes. ATP injections did not reduce radiation induced deletion of the X chromosome or induced crossing-over in males.

The data gathered by many researchers in the last decade and a half have indicated that some radiation-induced genetic injury is reparable. Among the pioneer workers in this field, Lea (1946) calculated that 95% of the chromosomes broken by radiation rejoin. Numerous researchers have since employed various pre- and postradiation treatments with gasses and chemicals and have also used fractionation and dose rate experiments, from these studies it was interpreted that radiation-induced genetic damage was not irreversibly fixed and that a repair system existed. Treatments which decreased metabolism in the postradiation period such as carbon monoxide, anaerobiosis, cyanide, inhibited rejoining of radiation-induced chromosomal breaks in plants (Wolff and Luippold, 1955). Sobels (1964) reported that postradiation treatment with cyanide or N_2 inhibited a repair process thereby increasing the yield of mutations in spermatids of Drosophila. Wolff and Luippold (1955) believed that the increase in genetic damage was a result of an inhibition of a repair process which required energy from oxidative respiration to function properly. Indeed, adenosine triphosphate, (ATP) was a product of oxidative metabolism and when used exogenously did reduce radiation-induced chromosome aberrations in *Vicia faba* (Wolff and Luippold, 1955), in microspore division of *Tradescantia* (Beatty and Beatty, 1960, 1966) and in *Trillium* (Iwabuchii, Saho, Tanifuji, 1966) and did prevent the loss of X chromosomes in spermatogenesis of *D. melanogaster* (Mittler and U, 1966).

The work presented was the result of an investigation to determine whether exogenous ATP would reduce the frequency of radiation-induced recessive sex-linked lethals, dominant lethals, deletions of the X chromosome, translocations between chromosomes 2 and 3 and crossing-over in the spermatogenesis of *D. melanogaster*.

Materials and Methods

The male flies were irradiated in No. 000 perforated gelatin capsules with x-rays from a G. E. Maximar 250-III unit at 150 KV, 15 ma, 35 cm distance, at a rate of 140 R/min as determined by a Victoreen Model 570 condenser R-meter with 100R and 250R chambers. Approximately 0.1 μl (as determined by increase in weight) of either 0.85% NaCl, (controls) or 5 mg of ATP/ml in 0.85% NaCl was injected into the dorsal region between the 3rd and 4th tergites with a needle drawn to a tip of approximately 0.06 mm. The ATP was obtained as crystalline disodium from Nutritional Biochemicals Corp. The amount of ATP injected was equivalent to 666 mg of ATP/kg of Drosophila. The males were mated at a ratio of one to three females and transferred to new groups of females daily (every two days in the deletion test). By this "brood method" the effect of radiation on the cells in various stages of spermatogenesis could be ascertained. for the 0-1 day brood represented mature spermatozoa at the time of the radiation exposure, while those offspring from the 5-7 day broods represented cells in meiosis and broods from 8-12 days represented spermatogonia (Auerbach, 1954, Lüning, 1952).

The recessive sex-linked lethals and translocations were detected by the mating of y sc^{Sl} In dl-49 sc^{8}; bw; st p^{p} females to injected $X^{c2}yB/Y$ sc^{8} y+ males. The adult males were 2-6 hours old when injected and irradiated with 1000R or 1600R of x-rays in air. The F_1 males were backcrossed to virgin y sc^{Sl} In dl-49 sc^{8}; bw; st p^{p} females. The absence of brown and scarlet-pink to occur in the F_2 offspring indicated a 2-3 translocation. The F_1 females mated individually, and the absence of any Bar-eyed males in a culture of at least ten F_2 males indicated a recessive lethal on the ring X chromosome. The genetic markers of stocks used are fully described by Lindsley and Grell (1967).

The deletion of the X chromosomes was obtained by mating 2-6 hr. old Oregon-R males which had been injected and irradiated at 2000R to y cv v f/Y; K-pn ca/+ females. These females were obtained by an automatic virgin female technique from a cross between y cv v f; K-pn ca with *pn* males, in which only females were produced. A large deletion would result in inviable males, but could be detected in attached -X females by the presence of exceptional females. These flies would have a wild body color and the absence of one or more of the three mutants due to the presence of the dominant wild alleles in the deleted X. A whole X chromosome in combination with the attached X was usually lethal, although if these meta females emerged, they could be distinguished easily by their crumpled wings and rough eyes.

Crossing-over was induced in ru h th st cu s e^{s} ca/+ males by irradiation after they were injected with ATP. The males were then mated at the ratio of 1 male to 3 females for days 1-3 and for days 4-6. On the seventh day the males were mated individually every day until day 15. There were two series of experiments: in one, males were injected with ATP or saline, irradiated and permitted to recover in air; in the other, males were injected, pretreated in N_2 for 30 minutes, then irradiated in N_2 and permitted to recover in air.

In the dominant lethal tests, 2-6 hr. old $X^{c2}yB/Y$ sc^{8} y+ males were injected either with saline or ATP, x-rayed with 1600R and then mated daily to *y w f* females. These were the same stocks in which exogenous ATP had been shown to aid in reducing the number of radiation induced XO males by preventing the loss of a ring chromosome (Mittler and U, 1966). In the series in which the males were irradiated in N_2 and

TABLE 1.—Effect of ATP pretreatment upon radiation-induced recessive sex-linked lethals and translocation in Drosophila males. Totals are of all broods of the sperm sampled from days 0 to 12.

Pretreatment	Percent of Recessive Lethal	Total Gametes	Percent of Translocation	Total Gametes
		1000R		
ATP	2.91	4841	2.74	877
0.85% NaCl (control)	2.70	4849	2.57	817
		1600R		
ATP	3.53	1924	4.79	1316
0.85% NaCl (control)	3.30	1876	3.50	1287

posttreated in N_2 three day old isogenic Oregon-R males were injected and irradiated with 1600R of x-rays. The mated females were isolated in plastic tubes having one end covered by a nylon mesh through which eggs could be deposited. This method was a modification of that used by Abrahamson and Herskowitz (1957) to prevent counting eggs from an unmated female. A cluster of 18 tubes was placed on agar-cornmeal media darkened with black-strap molasses in a 150 mm petri dish with no live brewer's yeast. Females were permitted to lay eggs for 48 hours after mating. In the first series, the males were injected with ATP or saline (control), irradiated in air and permitted to recover in air. In the second series the flies were irradiated in air after ATP or saline injection but were posttreated for 40 minutes in N_2. In the third series, the males were injected with ATP or saline pretreated with N_2 for 10 minutes, then irradiated in N_2 and posttreated in N_2 for 40 minutes. (A high purity grade of commercial N_2 flowing at a rate of 1500 ml/min was used in N_2 exposures.)

RESULTS

The frequency of sex-linked recessive lethals and translocations between chromosomes 2 and 3 induced by x-rays was not influenced by pretreatment with ATP (Table 1). There was no significant difference between the control and any of the daily broods at 1000R or 1600R. The sum totals of these daily broods are presented in Table 1. The lower dose was employed to obtain more offspring at the radiation induced semi-sterile period of 5-8 days after irradiation, for it was in this period of spermatogenesis that exogenous ATP did prevent chromosome loss in *Drosophila melanogaster* (Mittler and U, 1966).

The injection of exogenous ATP did not reduce the percentage of radiation induced deletion of X chromosome in daily broods (Table 2). A chi square larger than 3.85 as determined by a 2 x 2 contigency table was considered to be a significant difference.

TABLE 2.—Effect of ATP upon radiation-induced deletion of the X-chromosome after 2000R. Total is from all daily broods sampled 1 to 12 days after irradiation.

Pretreatment	Total Gametes	Percent of Deleted X chromosomes
ATP	12,536	2.47% $X^2 = 1.58$
0.85% NaCl (control)	9,415	1.59%

Inconclusive results were obtained with exogenous ATP and radiation induced crossing-over frequencies in

TABLE 3.—Crossing-over frequencies induced in $\frac{rh\ h\ th\ st\ cu\ s\ e^s\ ca}{+\ +\ +\ +\ +\ +\ +\ +}$ males irradiated at 3000 R.

Treatment	Brood day						
	9	10	11	12	13	14	15
ATP-air-R-air[1]	(0.0) 0/109	(1.87) 58/3108	(1.75) 29/1657	(0.63) 38/6005	(0.83) 90/10916	(1.09) 114/13229	(0.61) 62/10104
Saline-air-R-air	(0.0) 0/307	(2.06) 51/2471	(2.69) 21/782	(0.98) 48/4880	(1.93)[a] 131/6799	(0.65)[b] 58/8904	(0.67) 48/7217
ATP-N_2-R-air[2]	(0.47) 8/1695	(0.56) 18/3199	(0.42) 15/4325	(0.34) 18/5267	(0.67) 39/5807	(0.51) 18/3514	(0.0) 0/3281
Saline-N_2-R-air	(0.10) 1/1003	(0.71) 34/4765	(0.47) 18/3818	(0.28) 16/5636	(0.37) 26/7123	(0.27) 10/3665	(0.52)[c] 23/4386

[a]$X^2 = 40.429$ [b]$X^2 = 10.766$ [c]$X^2 = 15.548$

[1]Injection with ATP 5 mg/ml irradiated air and permitted to recover in air.

[2]Injection with ATP pretreated with N_2 for 30 and then irradiated in N_2 and permitted to recover in air.

TABLE 4.—Effect of 5 mg/ml of ATP injected in male Drosophila on radiation-induced dominant lethals. Radiation was 1600R of x-rays in air or nitrogen. The flies were permitted to recover in air or posttreated in N_2 for 40 minutes. The chi square was calculated by means of a 2 x 2 contingency table with Yates' correction.

Brood day	Injection	Radiation	Posttreatment	Total number of eggs	Percent undeveloped	X^2
0-1	ATP	air	air	2216	43.32	1.004
	Control	air	air	1273	41.73	
	ATP	air	N_2	354	62.43	1.022
	Control	air	N_2	428	58.88	
	ATP	N_2	N_2	1500	30.066	3.272
	Control	N_2	N_2	1377	35.602	
1-2	ATP	air	air	5051	40.74	4.454
	Control	air	air	3966	38.55	
	ATP	air	N_2	1191	31.07	.003
	Control	air	N_2	2262	31.17	
	ATP	N_2	N_2	4376	32.586	.0094
	Control	N_2	N_2	3204	32.771	
2-3	ATP	air	air	5177	37.14	99.776
	Control	air	air	5567	46.69	
	ATP	air	N_2	2177	47.08	23.39
	Control	air	N_2	5301	40.99	
	ATP	N_2	N_2	2327	26.69	14.49
	Control	N_2	N_2	3056	33.31	

TABLE 4.—Continued

Brood day	Injection	Radiation	Posttreatment	Total number of eggs	Percent undeveloped	X^2
3-4	ATP	air	air	3628	49.89	.473
	Control	air	air	4481	50.66	
	ATP	air	N_2	4695	48.41	.063
	Control	air	N_2	5571	48.66	
	ATP	N_2	N_2	4120	28.73	19.788
	Control	N_2	N_2	3964	35.19	
4-5	ATP	air	air	4654	52.13	58.189
	Control	air	air	3529	60.58	
	ATP	air	N_2	2300	57.87	15.274
	Control	air	N_2	3533	62.98	
	ATP	N_2	N_2	3878	39.53	15.501
	Control	N_2	N_2	3239	35.94	
5-6	ATP	air	air	3047	60.55	8.552
	Control	air	air	3416	64.08	
	ATP	air	N_2	1436	75.21	1.969
	Control	air	N_2	1787	73.03	
	ATP	N_2	N_2	3118	43.87	0.8286
	Control	N_2	N_2	3635	42.09	
6-7	ATP	air	air	1920	66.61	8.336
	Control	air	air	2198	70.79	
	ATP	air	N_2	1792	71.49	0.386
	Control	air	N_2	2481	72.27	
	ATP	N_2	N_2	2223	53.26	0.548
	Control	N_2	N_2	2197	51.20	
7-8	ATP	air	air	1704	58.69	0.509
	Control	air	air	1428	59.94	
	ATP	air	N_2	1784	74.55	0.386
	Control	air	N_2	2158	73.68	
	ATP	N_2	N_2	2380	61.26	15.21
	Control	N_2	N_2	2733	55.95	

TABLE 4.—Continued

Brood day	Injection	Radiation	Posttreatment	Total number of eggs	Percent undeveloped	X^2
8-9	ATP	air	air	990	64.24	0.601
	Control	air	air	748	62.43	
	ATP	air	N_2	986	69.27	3.273
	Control	air	N_2	1109	65.66	
	ATP	N_2	N_2	981	46.59	0.202
	Control	N_2	N_2	1441	48.27	
9-10	ATP	air	air	890	49.21	1.47
	Control	air	air	611	52.54	
	ATP	air	N_2	1488	56.99	63.755
	Control	air	N_2	2133	43.51	
	ATP	N_2	N_2	1637	40.20	0.386
	Control	N_2	N_2	1537	41.96	
10-11	ATP	air	air	884	44.68	0.904
	Control	air	air	785	47.01	
	ATP	air	N_2	997	44.73	0.00
	Control	air	N_2	1411	44.72	
	ATP	N_2	N_2	1257	28.24	5.67
	Control	N_2	N_2	1939	33.88	
11-12	ATP	air	air	186	46.77	4.091
	Control	air	air	281	37.37	
	ATP	air	N_2	1562	44.37	9.939
	Control	air	N_2	1984	39.11	
	ATP	N_2	N_2	1444	20.152	15.250
	Control	N_2	N_2	1512	28.108	

the male Drosophila (Table 3). The ATP did not have any effect on broods of day 10, 11 or 12, however, in the series irradiated in air, the males injected with ATP had significantly less crossing-over in brood of day 13, however, in brood of day 14, the males injected with saline had significantly less crossing-over. In the nitrogen-irradiated series, the brood of day 15 which was produced by the saline injected males had significantly more crossing-over than the brood of the ATP treated males.

In the dominant lethal series (Table 4), the injection of ATP before irradiation in air and recovery in air did significantly enhance the number of eggs that did develop in broods of day 2-3, 4-5, 5-6, 6-7, however, the number of eggs that failed to hatch was increased in broods of day 1-2

and 11-12. In the second group in which the pretreatment consisted of saline or ATP before irradiation in air and then followed immediately by posttreatment with N_2, the protection due to ATP was limited to brood day 4-5 which represented spermatids at the time of x-ray injury. The ATP injection did significantly increase the percentage of dominant lethals as compared to the controls in brood day 2-3 and 9-10. In the third group of dominant lethal experiments in which the males were irradiated and posttreated in N_2, the injections of ATP did significantly decrease the dominant lethals in brood day 2-3, 3-4, 10-11, and 11-12. However, there was an increase in dominant lethals frequency in brood day 4-5. Irradiation in N_2 and posttreatment in N_2 induced the males to produce a lower percentage of dominant lethals (as compared to the above two other groups) in ten out of the twelve daily broods.

The irradiation in air resulted in a greater percentage of dominant lethals than irradiation in N_2. This occurred in all broods and was expected. The Drosophila males that were irradiated in air and posttreated in nitrogen had an increase in percentage dominant lethals compared to the eggs that were fertilized by males irradiated in air and permitted to recover in air on brood day 0-1, 5-6, and 7-8 and decrease in dominant lethals in brood day 1-2.

Discussion

Exogenous ATP did not have any effect upon radiation induced sex-linked lethals frequencies in the ring X chromosome. These lethals were apt to be "point mutations" rather than large deletions which would have resulted in the loss of the ring chromosome. Sex-linked lethals in Drosophila which have been induced by x-ray treatment in nitrogen were reported by Sobels (1964) to be decreased in mature spermatozoa by N_2 posttreatments while O_2 posttreatment reduced the lethals in spermatids. ATP in the work reported here did not have any influence on any of the stages of spermatogenesis with respect to radiation induced recessive lethals. Several of the broods indicated that ATP did lower the percentage of induced dominant lethals. Either the radiation in air damaged the mutation repair system to such an extent that the additional exogenous ATP could not be utilized or that there may exist major differences between repair and recovery of dominant lethals and that of recessive lethal mutations with respect to ATP utilization. Biswas and Matsuo (1966) also reported that pretreatment with ATP did not alter the rate of x-ray induced chlorophyll mutants in rice.

The injection of ATP failed to prevent radiation induced translocations between chromosomes 2 and 3, and deletion of the X chromosome or crossing-over in male Drosophila. These aberrations involved breakage of chromosomes. Extra amounts of ATP (if it is indeed helpful) should have aided in the recovery and decreased the percentage of the aberrations. In the translocation and deletion tests, the radiation damage occurred in cells during the various stages of spermatogenesis but the presence of certain adult phenotypes many cell divisions later were used to assess the damage. In the experiments with recessive lethals, the mutations were detected two complete life cycles later. The long interval between the time of exposure to radiation and the assessment of the damage would eliminate any chromosome that was not "properly" repaired.

The data obtained from radiation-induced dominant lethal experiments does indicate that in some broods there was a reduction in a percent-

age of those radiation induced lethals induced in air and permitted to recover in air as the result of the ATP injections. These broods represented immature spermatozoa, spermatids and spermatocytes at the time of irradiation. The reduction in the induced dominant lethals can be attributed to the repair of broken chromosomes aided by ATP. This is in accordance with a hypothesis proposed by Wolff and Luippold (1955) that the chemical bonds formed in rejoining chromosomes broken by radiation required ATP as a source of energy. Exogenous ATP did decrease the time of reunion of broken chromosomes in the root tip of *Vicia faba,* while inhibition of ATP formation by dinitrophenol increased the time the broken chromosomes were apart (Wolff and Luippold, 1956). Beatty and Beatty (1960) also reported that exogenous ATP reduced radiation induced chromosomal aberrations in the meiosis of *Trandescantia.* Swabuchi, Saho, Tanifugi (1966) found that ATP treatment reduced radiation induced chromosome aberration in ovular tissue of *Trillium.*

When the males were injected with ATP irradiated in air and posttreated in N_2 only in one brood (spermatids) was the dominant lethals reduced. This was unexpected for if the repair of broken chromosomes was inhibited by anerobiosis and dependent upon oxidative metabolism with resulting ATP formation, then exogenous ATP could have aided in the repair process. Either the exogenous ATP was utilized in the repair process only if oxygen was present or the nitrogen posttreatment with the resulting increase in dominant lethals overwhelmed whatever recovery effect the ATP imported to dominant lethals so that the end result was no decrease in dominant lethals. The work of Sankaranarayanan (1967) indicated that nitrogen posttreatment of 30 min. as used in the above dominant lethal experiments would have no effect at least on mature spermatozoa with respect to an increase in dominant lethals.

The chromosome imbalance theory of dominant lethals leads one to think that all dominant lethals are due to chromosome breakage, loss or rearrangement. The prevention of the loss of chromosomes or deletions as the only means of reduction of dominant lethals may not present the entire picture of dominant lethals. Von Borstel and Rekemeyer (1959) reported that the majority of radiation-induced dominant lethals which resulted in an early death of the embryos of Drosophila and Habrobracon was not similar to those that were produced genetically by the loss of chromosomes. A mitotic block was proposed to produce the dominant lethals. However, one cannot distinguish whether this mitotic block was due to chromosome loss or rearrangement or some other induced damage and change. Whatever these changes may be, the response by brood testing indicated in the work presented here that a percentage of radiation induced dominant lethals was greatest in early spermatids and the least in spermatogonia. Exogenous ATP did significantly reduce the percentage of induced dominant lethals in spermatozoa, spermatids and spermatocytes.

Acknowledgments

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THE FLOODING PATTERN IN ILLINOIS STREAM BOTTOMLANDS, HAS IT CHANGED SINCE PRIMITIVE TIME?

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ABSTRACT.—An analysis of discharge rates, flood pool levels, and frequencies of flooding in the upper Sangamon River bottomlands in east central Illinois, as registered on the Monticello river gage, shows that no significant differences due to man's influence occur between the flooding pattern at the present time and the period 1908 to 1920. In 1908, modification of upland drainage through organized drainage districts extended over approximately 9.7 to 12 per cent of the drainage basin; in 1920, 30 to 32 per cent; and at the present time, 50 per cent. The bottomland natural area in the Robert Allerton Park, three miles southwest of Monticello, may therefore be considered still to have an essentially primitive flooding pattern.

The biennial report of the Illinois Nature Preserves Commission for 1969-1970 lists a number of proposed and dedicated Nature Preserves that include streams and bottomland forest ecosystems. The vegetation and animal life in several of these areas may represent the closest approach to primitive biotic communities now possible to acquire, and with inclusion in the Nature Preserves System there is some guarantee that they will be maintained in a natural state relatively free of deliberate man-made disturbance. The flooding pattern over the bottomlands is determined, however, by regional precipitation, terrain, and agricultural practices extending far beyond the limits of the Preserves and are not under immediate control. The purpose of the present paper is to examine one such bottomland ecosystem to determine, if possible, the extent that the flooding pattern has changed since man settled in the area. This study also has relevance in relation to the establishment of a State Scenic River System and to the choice of rivers most nearly simulating natural conditions for inclusion in this System.

The Robert Allerton Park, located near Monticello in east-central Illinois and owned by the University of Illinois, contains over 600 acres of bottomland forest. The State of Illinois is proposing the construction of Oakley Reservoir, north of Lake Decatur, by the Army Corps of Engineers, which if completed, would alter the natural flooding pattern in the Park (Kendeigh *et al.* 1970). Proponents of the project argue that the flooding pattern is already considerably changed from the primitive, that the Park is not therefore a natural area of historic and evolutionary value, and that, consequently, further changes in the flooding pattern will not be of significance. Floods are thought now to be greater and to come at more frequent intervals, due to better drainage of the upland, and that the effect on runoff has been especially dramatic since about 1920 (Ackermann 1971).

We can only postulate what the drainage pattern was like in primitive times or even after man first began to cultivate the land. However, a comparison of the flooding pattern of the Sangamon River above Allerton Park before and after 1920 may furnish some indication of the direction of any changes that have occurred, and by projection backwards, the flooding pattern in primitive time might be reconstructed. A water level gage was first installed in the river at Monticello in 1908. Except for 1913 and the first half of

1914, data on rate of discharge and height of floodpools are available continuously to the present. The discharge rate during a flood on March 26, 1913, was estimated from the rainfall. There was no flood in 1914. The drainage basin above the Monticello gage is approximately 550 square miles (Mitchell 1954) and above Allerton Park about 600 square miles.

The upper Sangamon basin was part of an extensive area in east-cen-

TABLE 1.—Drainage districts in the Sangamon River watershed above Allerton Park (modified from Pickels and Leonard 1921 1929) 4.

Reference number	Name of district	County	Date organized	Area in acres
	Probably functional before 1908			
4	Hillsbury Slough Special	Champaign, Ford	1898	5,960
5	Wild Cat Special (including East Bend Mutual)	Champaign, Ford	1898	10,400
6	Big Slough Special	Champaign, Ford	1886	16,200
15	Goose Creek No. 3	Piatt	1903	1,740
	Other districts functional before 1920			
1	Sangamon	McLean	?	3,760
2	Sangamon and Drummer	Champaign, Ford	1909	7,720
3	Ford and Champaign Tile	Champaign, Ford	1913	500
9	Camp Creek Special	Champaign, Piatt	1906[1]	13,600
10	Newcomb Special	Champaign, Piatt	1908	6,400
11	Owl Creek	Champaign	1914	2,800
12	Lotus Special	Champaign, McLean, Piatt	1907	32,500
13	Goose Creek No. 1	Piatt	?	1,000
14	Goose Creek No. 2	Piatt	?	900
16	Goose Greek No. 4	Piatt	?	1,400
18	Willow Branch No. 10	Piatt	?	1,640
19	Willow Branch No. 4	Piatt	?	540
	Becoming functional between 1920 and 1929			
1	Sangamon (expanded in size)	McLean	?	3,100
7	Condit No. 1	Champaign	1881[2]	3,440
8	Jersey	Champaign	1925	400
17	DeWitt Special	DeWitt, Piatt	1909[3]	9,540

[1]Pickels and Leonard (1921) state that this district did not complete its ditches until 1911 and contained 13,600 acres, not 14,600 as called for in the original plans.

[2]Although the County Clerk states that a special report in his files indicates that the district was organized in 1881, no further records are available on it until 1959. Pickles and Leonard do not show it on their 1920 map but it is on their 1929 map.

[3]Pickles and Leonard (1921) report work in this district was not completed in 1920.

[4]Since going to press, Ray C. Dickerson's "Inventory of Illinois drainage and levee districts", Illinois Dept. Bus. Econ. Devel., Div. Water Nat. Res., 1971: x + 955, has become available. Dickerson gives "date organized" for "reference number" 1-1912 (expanded in 1925), 2-1908, 5-1886, 6-1880, 11,1911, 13-1905, 14-1905, 17-1910, and 18-1912.

tral Illinois acquired from the Indians in 1819. The human population in 1830 was less than two per square mile and had risen to an average of only about 30 per square mile in 1860. The upland prairie soil was demonstrated suitable for the growing of corn by 1850, and during the following decade agriculture more than doubled (Cole 1919).

Man's activities conceivably affected the rate of run-off from the uplands into the river by removal of the prairie grasses, tiling of the farmland, and deepening and straightening of the stream channels. The effect of removal of the grasses is mitigated to some extent by their replacement with farm crops over part of the year, and the removal of the grasses was probably not very important to the drainage as much as it allowed an increase in erosion of the soil. In the early days only the higher ground could be cultivated regularly, and water stood in the depressions "until it evaporated or found its way slowly through the soil to the natural channels" (Pickels and Leonard, 1921). In the upland, the percentage of the land having less than 2 per cent slope varied between counties from 40 to 80 (Warren and Van Praag 1948). Farmers sometimes improved the drainage from individual fields by tiling, but there is no evidence that this had much effect on drainage over large areas of land.

The Farm Drainage Act, passed by the State Legislature in 1879, en-

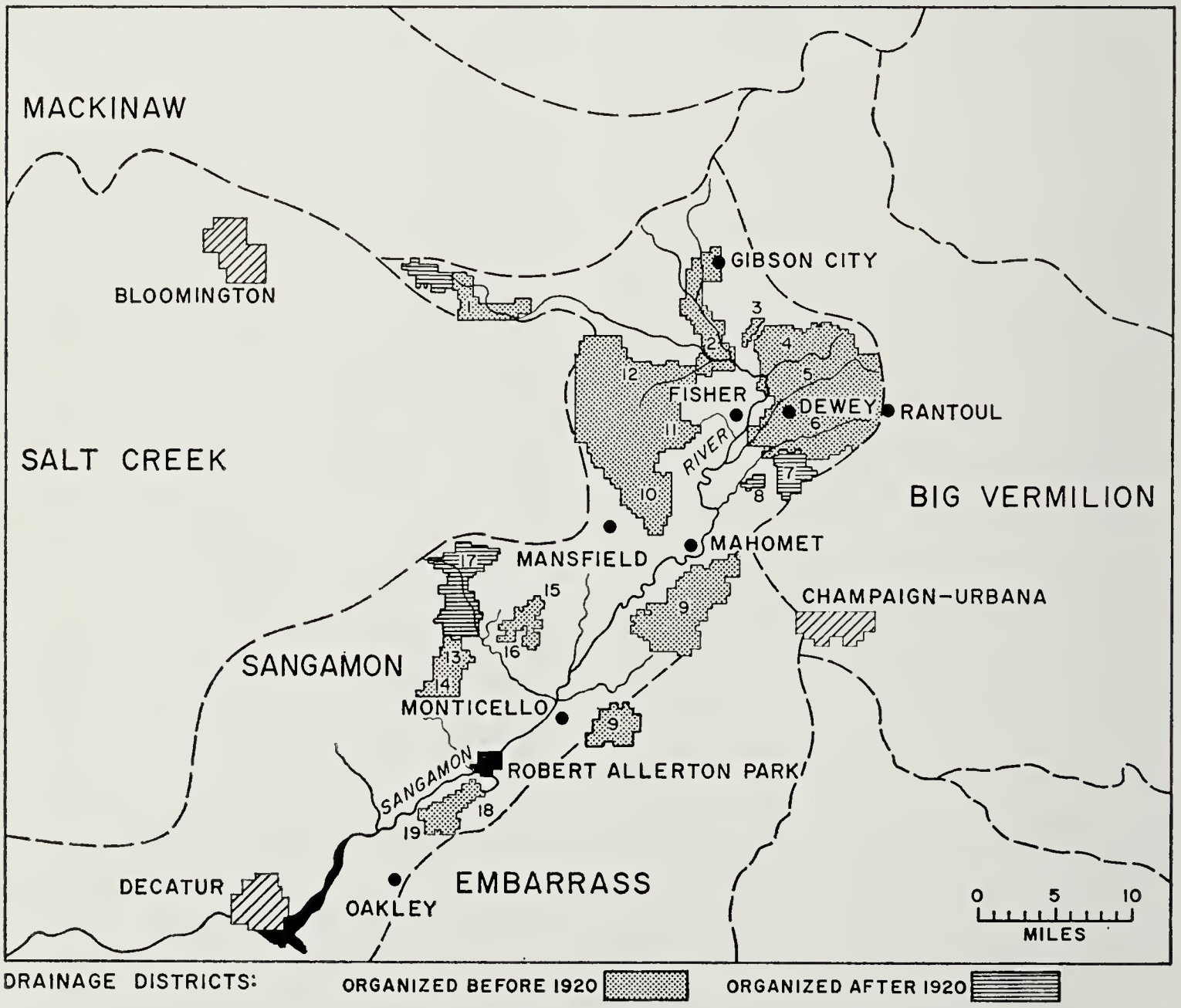

FIGURE 1.—Drainage districts in upper Sangamon River basin (modified from Pickels and Leonard 1921, 1929).

couraged the deepening of streams by dredging, straightening of channels, and construction of open ditches where previously there had been none. This permitted more thorough and deeper tiling of farmland and the cultivation of lands earlier impossible because of saturated soils throughout the year. Table I lists drainage districts in the Sangamon River basin above Allerton Park previous to 1929 and figure 1 maps their location and distribution.

Of the 19 drainage districts, only 4 were apparently functional before 1908. The acreage of these 4 districts constitutes only 8.9 per cent of the drainage basin above Allerton Park. Even if the 6 additional districts established before 1920 but whose exact dates of organization are unknown were functional before 1908, this would be only 11 per cent of the basin area. The amount of time elapsing from a drainage district being organized and becoming entirely functional varied but required at least several months and sometimes years. By 1920, the 16 organized and probably functional districts covered 28 per cent of the basin or if the DeWitt Special is included, 30 per cent. By 1929, the coverage was 32 per cent. At the present time, roughly 45 per cent of the basin is covered by drainage districts, although there is uncertainty as to how well they are being maintained. This percentage is less than in some other parts of the State. Pickels and Leonard (1921) state that "fully 75 per cent of the area north of the river between Decatur and Monticello is either within districts or is now [1920] being incorporated within districts . . ." For the area above the Monticello rain gage, the drainage districts in 1908 covered 9.7 or possibly 12 per cent; in 1920, 30 or 32 per cent; in 1929, 35 per cent; and at the present time 50 per cent.

Fortunately, there was a period of heavy rains in April and May of 1908 that produced a recorded flood on the river gage at Monticello, and the magnitude of these rains was almost exactly duplicated during December, 1949, and January, 1950. A comparison of the rate of water flow, height attained, and duration of these two floods nearly 42 years apart is of interest, since one came mostly before and the other after the modification of drainage in the upland farmland. If the ground were frozen during the winter of 1949-50, the run-off would have been accelerated, but temperatures averaged above freezing for the months of December and January, in fact they were several degrees higher than normal (Table 2).

Graphs of these two floods are very similar, both at the Monticello gage and as projected for the Allerton Park bridge (fig. 2). The 1908 flood reached a higher discharge rate (9600 cfs) and flood level (638 ft), while the 1949-50 flood, with a lower peak discharge rate (7600 cfs) and height (637.6 ft), persisted a little longer. Fluctuations in the pool stage elevation are related to the daily patterns of rainfall and are proportional to their magnitudes.

TABLE 2.—Weather statistics at time of 1908 and 1949-50 floods.

1908	Precipitation	Mean temperature	1949-50	Precipitation	Mean temperature	Departure from normal
March	3.20 in.	43.0°F.	November	1.00 in.	43.6°F.	+ 2.7°F.
April	5.00	50.3	December	5.00	36.3	+ 6.1
May	7.83	61.9	January	7.62	34.4	+ 7.5

Another comparison may be made for identical months in 1908 and 1927 when total rainfall was also nearly the same.

	1908	1927
March	3.20 in.	3.84 in.
April	5.00	6.48
May	7.83	5.01
Total	16.03	15.33

The pool-stage elevations for these two years (fig. 3) at the Monticello river gage criss-cross in an irregular manner, correlated with the daily pattern of rainfall. These rainfall data were obtained at Urbana which is not in the Sangamon drainage basin but is the nearest weather station where daily records are available. These two figures do not show any important change in the flood pattern induced by the artifical upland drainage.

The average frequency of floods per year after 1920 is slightly greater than it is for the 13 years from 1908 through 1920 (Table 3), but the difference is not statistically significant ($P => 0.5$). The difference is correlated, however, with an average annual precipitation before 1920 of 33.3 inches and after 1920 of 37.5 inches. The average annual frequency of floods for the last 13 years (1953 through 1965) was only 2.1. The average annual precipitation for this latter period was 34.7 inches.

There were 7 large floods with stream flows exceeding peak discharge rates of 7000 cfs from 1908 through 1920 or an average of one

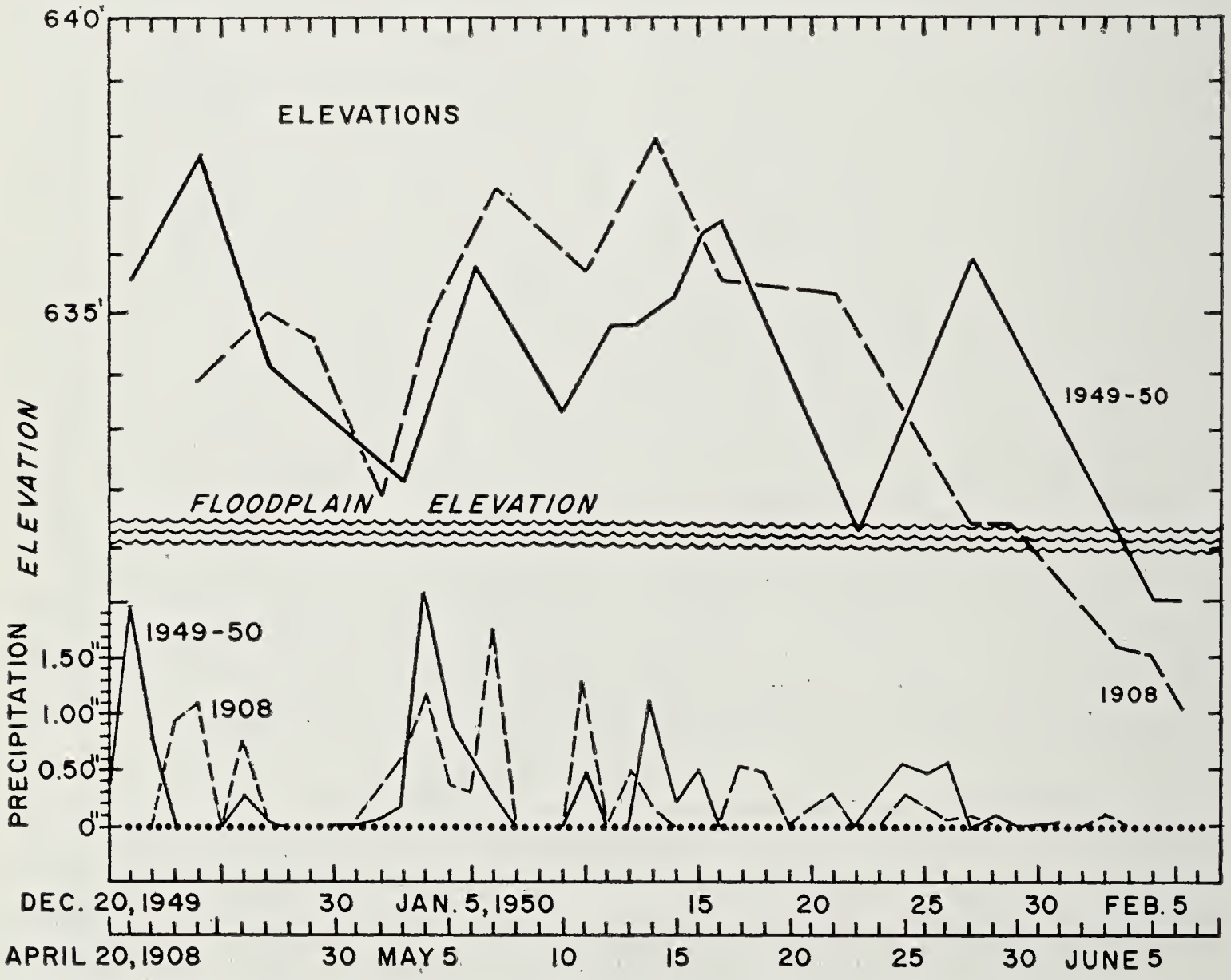

FIGURE 2.—Comparison of pool-stage elevations of the 1908 and 1949-50 floods at Allerton Park bridge as calculated by the Army Corps of Engineers, Chicago Office, July, 1968.

TABLE 3.—**Frequency of floods (>1800 cfs) during calendar years.**

Period	1908-20	1921-65	1953-65
Number of years	13	45	13
0/year	1	5	1
1	4	8	6
2	1	6	2
3	2	5	2
4	3	7	0
5	2	3	1
6		7	1
7		2	
8		1	
9		1	
Mean ± S.E.	2.6±0.47	3.4±0.36	2.1±0.49

every 1.9 years. There were only 13 such floods for the period from 1921 through 1965, or an average of one every 4.2 years. There were 5 such floods from 1953 through 1965 or one every 2.6 years.

Statistical analysis of these floods before 1920 and after 1920 shows a significant correlation between the discharge rate and the total rainfall of the month in which the flood occurred (the flood of October 4, 1926, is, however, correlated with rainfall in September rather than October). The two equations are:

1908-1920: $Y = 10{,}000 + 629\ (X - 5.6)$, SE: ± 1,200

1921-1965: $Y = 11{,}200 + 876\ (X - 5.6)$, SE: ± 1,000

The letter Y is the mean peak stream flow in cubic feet per second (cfs), the letter X is monthly precipitation in inches, and SE is the stardard error of the estimate. Neither the difference in the coefficients (629 cfs/1 in. before 1920 and 876 cfs/1 in. after 1920) nor the Y values are statistically significant ($P => 0.5$). The mean peak discharge for the period 1953 through 1965 was 10,670 cfs. This analysis again shows that large floods depend on rainfall and not on changes that have been made in the upland drainage.

In a report prepared for the City of Decatur (Warren and Van Praag, 1948), mean annual precipitation over the drainage basin above the river gage at Monticello was calculated for the period 1909 through 1946, except for 1913, by averaging data obtained at weather stations in Monticello, Urbana, Rantoul, Gibson

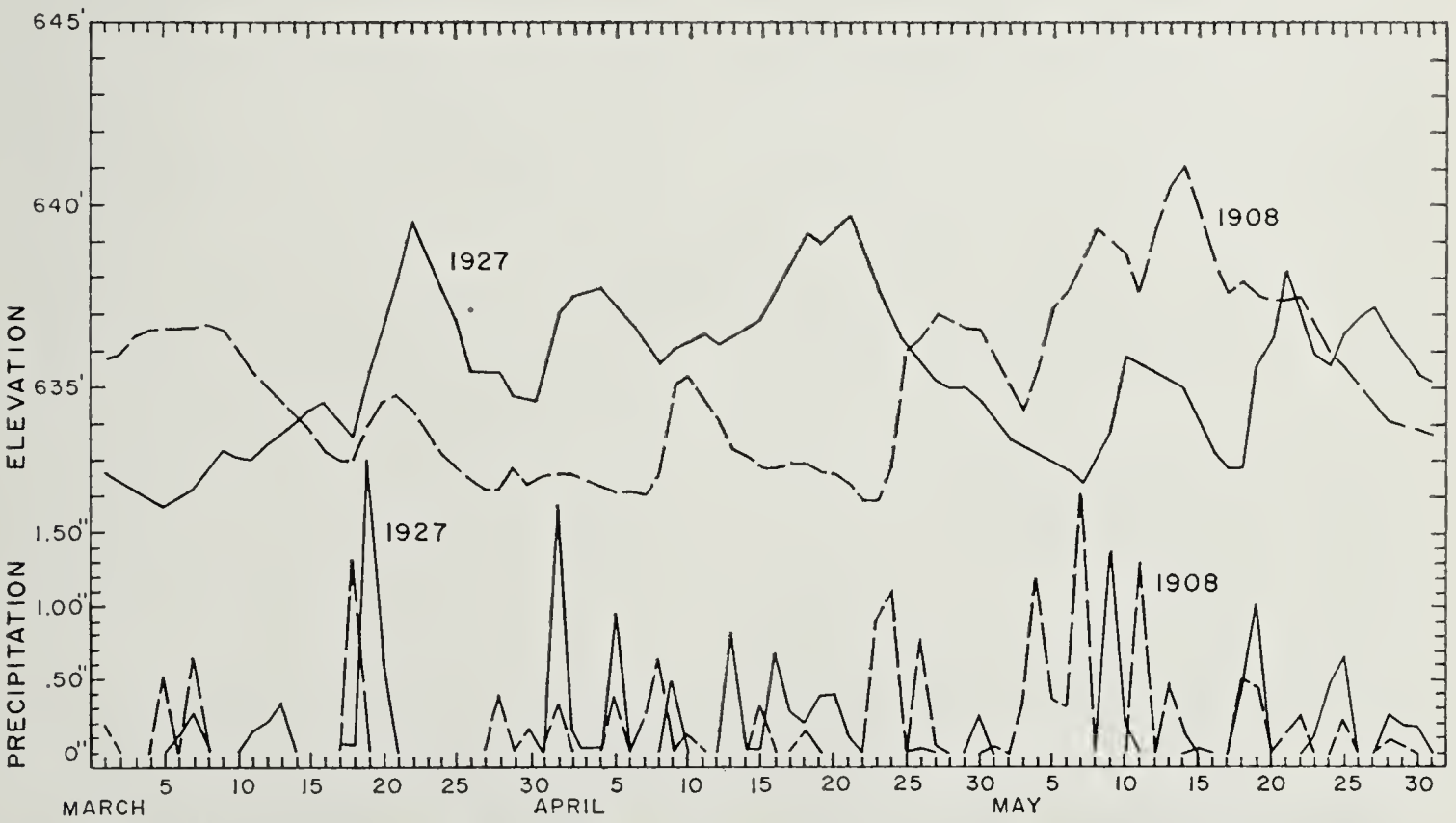

FIGURE 3.—**Comparison of pool state elevations of the 1908 and 1927 floods at Monticello.**

City, and LeRoy. The data for each station was weighted in proportion to the area of the watershed covered by each. The total annual discharge at Monticello of water down the river was then calculated in terms of "runoff depth in inches over the watershed". The mean annual runoff for the entire period, 9.97 inches, is given as 27.3 per cent of the mean annual precipitation, 36.15 inches. The percentage of runoff increases, however, the heavier the precipitation. With a precipitation of 25 inches, runoff is only 13.6 per cent; with a precipitation of 45 inches, it amounts to 34.2 per cent. The total runoff is plotted against the mean precipitation over the watershed each year in fig. 4. There is considerable scatter in the points and no consistent difference between years before and after 1920 as to whether they fall above or below the mean rate. Runoff has not been altered by the establishment of drainage districts.

A study similar to this but in greater detail was published in 1929 for the upper portions of the Des Moines and Iowa Rivers in Iowa (Woodward and Nagler 1929). The original vegetation and terrain were similar to east-central Illinois. Stream flow measurements were begun in 1903 before the Drainage Law was passed in 1904 and well before the drainage districts were mostly completed in 1917. Stream flow records were compared for the years 1903 through 1906, prior to the drainage modifications, with the years 1918 through 1923 when well over one-third of the land, and in some regions nearly all the agricultural land, was subjected to artifical drainage. The authors state, "a critical examination

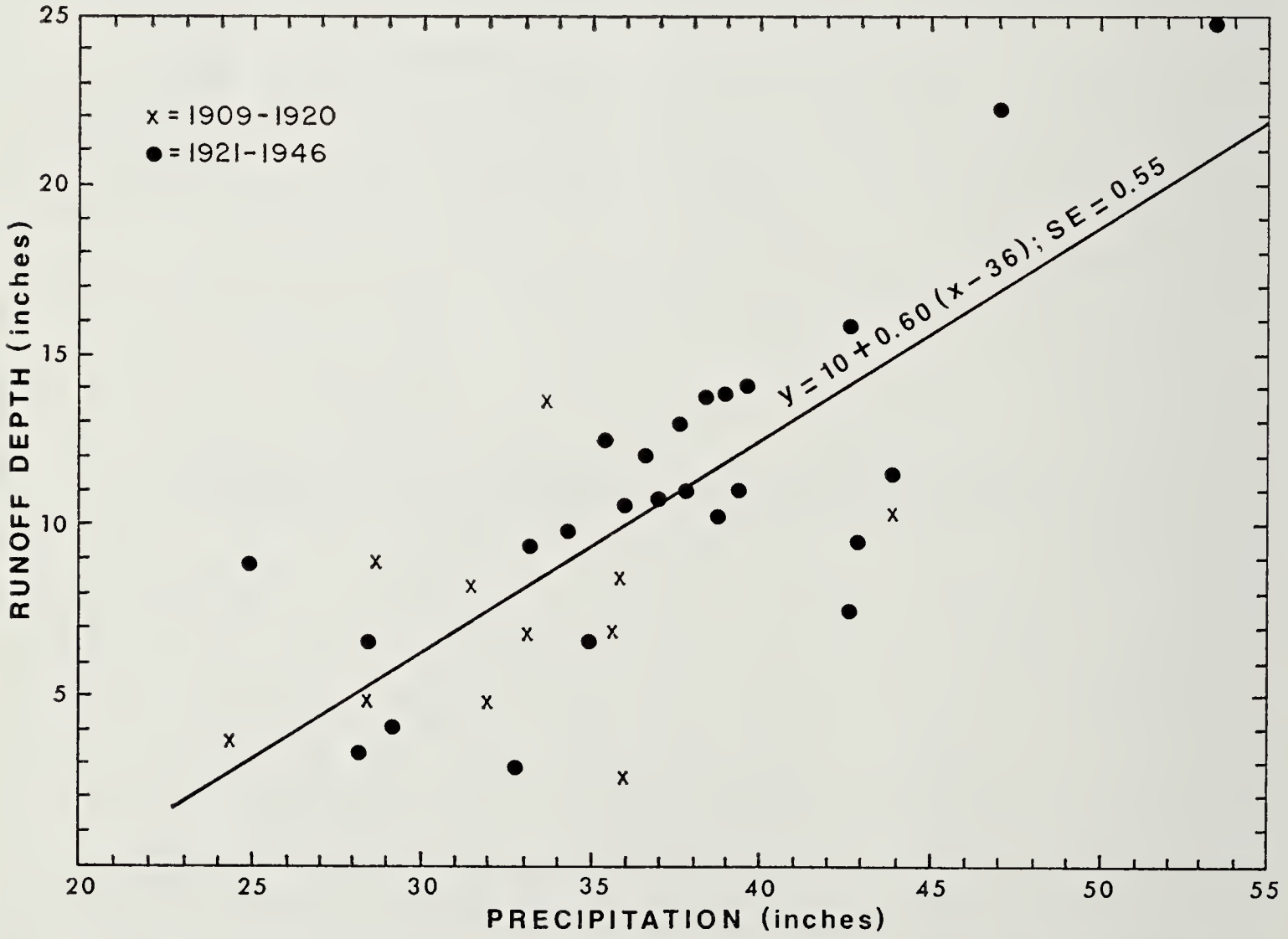

FIGURE 4.—Relation between depth of annual runoff and annual mean precipitation over the Sangamon River watershed above Monticello (data from Warren and Van Praag 1948).

of the records of these two streams shows that during flood periods there have been no significant change in their behavior which may be attributed to drainage. The total run-off from storms of like precipitation, the maximum rates of discharge, and the rain-water storage conditions within the basins seem to have been unaltered by the extensive drainage operations." This study fully substantiates the findings for the Sangamon River basin.

Why the altered upland drainage has no apparent effect on the flooding pattern is difficult to explain. The water table undoubtedly lies deeper in the ground now than it did in primitive time. After rains, probably more of the water now soaks into the ground rather than running into depressions and evaporating. Perhaps one effect compensates quantitatively for the other so that the net effect on the flooding pattern is the same.

In summary, there is no evidence available to show any significant change in the flooding pattern of Allerton Park since 1908. The fact that no significant change in the flooding pattern in the upper Sangamon River bottomlands can be demonstrated after 1920, when man had made the greatest alteration in the upland drainage, and before these alterations had been completed, indicates that essentially a natural primitive flood pattern still persists in the upper Sangamon River bottomlands. This gives added evidence for the characterization of Allerton Park as a natural area, and added weight for protecting natural areas throughout the State from any deliberate future modification by man.

Acknowledgments

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THE ORIGIN OF WEEDINESS

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ABSTRACT.—Weediness is the ability of an organism to adapt to a man-disturbed environment. The origin of weediness for any particular taxon has its source in the genetic variability available to the taxon and the plasticity of its expression. Weeds originate by selection for plasticity which directly mimics a crop ecologically and or morphologically. The variability that forms the basis of this selection originates from introgressive hybridization among colonizing species and hybridizations between a crop and its wild relatives.

Crops, weeds, colonizers, and wild taxa form a progression in descending order of their ability to survive in man-disturbed habitats. Weedy plants are adapted to selection regimes as established by man's activity, and cannot compete successfully with wild plants in their stable environments (de Wet, 1968). Disruption of habitats can be brought about by both natural and man-made forces. The mere presence of man results in disruption. Since the beginnings of agriculture, man's activities have accounted for ever greater and more rapid disturbances. The objective of this paper is the discussion of the origin of the genetic systems responsible for weediness, and the plasticity of their expression.

PHENOTYPIC PLASTICITY IN WEEDS

Although an important adaptive characteristic in all plants, phenotypic plasticity is exploited to a greater extent by weeds. Phenotypic plasticity is the ability of the same genotype to produce different phenotypes under various environmental regimes. It is also the ability of different genotypes to appear as one phenotype. Bradshaw (1965) discussed the evolutionary significance of plasticity in plants with regard to various selection regimes. Disruptive selection, which results from recurrent fluctuations of the environment in space and time is commonly encountered by weeds and non-weeds. Bradshaw indicated that annual weeds such as *Chenopodium album* and *Poa annua* were more plastic under disruptive selection than their nearest perennial relative. Annuals have evolved a more plastic form than perennials of the same genus. Agriculture gives rise to disruptive selection on a tremendous scale, and plasticity that mimics the crop is of great adaptive advantage.

Stebbins (1950) indicated that in the weed species *Camelina sativa* two forms exist. One form is very plastic, found in various agricultural fields, and has a normally branching growth pattern. When this form is found in flax fields, it appears taller and less branched. This is perhaps related to the density at which the flax is planted. In areas where flax is cultivated on a more extensive scale, *C. sativa* var. *linicola* appears. It is less plastic and has a genetically based form which mimics flax. Selection in this has been for plasticity and for genetically fixed mimicry. The amount of plasticity will vary between populations of the same taxon as is the case for *Capsella bursa-pastoris* (Bradshaw, 1965).

Directional selection demands that one environmental factor be met if the plant is to survive. Any ecological factor that does not vary in a particular habitat enough to establish a dis-

ruptive selection, can be the causal factor in directional selection. Bradshaw (1965) discussed Turreson's data that demonstrated plasticity in *Atriplex latifolium, A. patulatum* and *Chenopodium album*. Under intense light these plants had a prostrate growth form, while under normal light the plants grew upright. The overall impact of plasticity is to allow the individual plant to survive stress which prevents its contribution to the gene pool from being lost. There is no available data that contrasts plasticity in weeds and nonweeds. A majority of taxa cited for their plasticity however, are weeds. Since the amount of plasticity varies among populations of a species, direct specific level comparisons would be meaningless.

Jain (1969) compared two weed taxa, *Avena fatua* and *A. barbata* in the amount of genetic and environmentally induced variation. *Avena fatua* and *A. barbata* are both predominantly inbreeding taxa, having less than three percent outcrossing. Genetic based polymorphism was high in *A. fatua* and low in *A. barbata,* whereas for overall pehnotypic plasticity the reverse was true. *Avena barbata* had greater overall phenotypic variability. Both species are introduced weeds from the Mediterranean area, both are polyploids, but their weediness originates from variability of different sources.

Baker (1965) indicated that many weed taxa exploit plasticity to a great degree by occupying widely divergent habitats and niches. He suggested that several of these taxa originate through hybridization as evidenced by their triploid and pentaploid chromosome numbers. Baker hypothesized that these hybrids have a genetype that allows for great plasticity. This "all purpose" genotype is fixed by vegetative propagation or apomictic forms of reproduction as is the case for *Oxalis corymbosa, Polypodium dispersum* and *Taraxacum officinale*. In *Taraxacum* sexual diploid races native to central Europe hybridize and form triploid apomictic forms. Adaptive types were able to spread beyond their geographical ranges to western and northern Europe as well as to North America (Stebbins, 1971). Solbrig and Vuilleumier (1970) reported that these introduced taxa formed very phenotypically variable populations in the United States as judged by exhibited isoenzyme polymorphisms.

Hybridization of Colonizing Species

Interspecific hybridization is the crossing of different adaptive gene complexes. The immediate effect of this is to increase greatly the amount of variability in the gene pool. Competition from better adapted parents generally precludes the existence of hybrids in the parental niche. Successful hybrids are more often found in non-parental niches. Disturbed opened areas are habitats available for newly created adaptive gene complexes. Hybridization is prevented between most taxa by pre and postzygotic mechanisms (Stebbins, 1966).

Colonizing species are those that are the first to enter a newly created habitat. They differ from true weeds in that they are not as successful in competing for permanently man-disturbed habitats. Species that are normally isolated geographically can be brought together by the expansion of their geographical ranges into areas disturbed by man. This phenomena occurred between *Bothriochloa grahamii* from the Ganges area of India and *B. ischaemum* from Eurasia. Introgressive hybridization between these two colonizing taxa created a series of highly variable weedy population in the Northwest of India (Harlan, 1963a; 1963b).

Accidental plant introductions is another means by which geograph-

ically isolated taxa can become sympatric. Several genera are represented in the United States weed flora by very diverse introductions. *Chenopodium* is represented by taxa from tropical America, Australia, Europe, Eurasia, and several native species. Other weed genera with diverse origins include: *Allium, Polygonum, Cardaria, Convolulus, Setaria, Amaranthus* etc.

When colonizing species are isolated because of hybrid sterility, hybridization followed by polyploidy can often act to restore fertility. The reasons for this are two-fold. Genetically determined pairing of chromosomes has been demonstrated in several amphiploid taxa. When these major genes are present polyploid taxa behave cytogenetically as diploids. This is best demonstrated with wheat, a hexaploid that forms twenty-one bivalents (Riley and Law, 1965). If the hybridization occurs between a tetraploid and a diploid or between two tetraploids, a common genome i.e. one that is shared between the two hybridizing taxa can act as a buffer allowing for introgression. Tetraploid by diploid hybridizations can form triploid F_1's that are partially fertile (Lewis, 1967). Triploids can serve as bridges between tetraploid genetic receivers and diploid doners. Vardi (1971) demonstrated that introgression can occur between tetraploid and diploid species and that by the third backcross generation there is a marked increase in tetraploid-like individuals and greater stability in meiosis in comparison to the original F_1.

Stebbins (1970) discussed the distribution of polyploidy in weeds and concluded that they do not contain significantly higher number of polyploids when compared to the non-weedy flora. Of 118 introduced weed genera 44 were diploid, 36 contained both diploid and polyploid taxa in both native and introduced areas and 28 genera had only polyploid taxa in the introduced area. Stebbins reported that in genera with both diploid and polyploid species the polyploid is more likely to be weedy.

Polyploidy when measured by chromosome number alone can be misleading. In *Lolium,* known in breeding weedy taxa had 35 percent more nuclear DNA than non-weedy outbreeding taxa. The DNA was found to proportional to chromosome volume and dry nuclear mass (Rees and Jones, 1967). All *Lolium* species appear as diploids (2n=14), but DNA content would suggest that in the weedy inbreeding taxa duplication of some aspects of the genome has occurred. Polyploid taxa are often capable of absorbing genetic information from several related species and using this to expand their geographical and ecological ranges. Species with these abilities are termed compilospecies. Since these are aggressive species they are often weedy or have weedy races. *Bothriochloa intermedia* (de Wet and Harlan, 1966), *Achillea millefolium* (Ehrendorfer, 1959), and *Aegilops umbellulata* (Pazy and Zohary, 1965) are examples of comilospecies.

In *Achillea* diploid species are isolated from each other genetically. This isolation allows for greater differentiation and morphological divergence. Tetraploid and hexaploid *Achillea* species have access to this wide variation. These polyploid complexes are characterized by hybridization with diploids followed by backcrossing to the polyploid parent which allows for the absorption of the genetic information from the diploids. Some of these polyploid taxa introgressively hybridize with each other to such an extent that they might be considered conspecific. The weed *Achillea millefolium* is composed of tetraploid and hexaploid races and throughout its range it can exchange genetic information with diploid, tetraploid and

hexaploid relatives. Weediness in this taxon is attributable to variation created by intogression among colonizing taxa and wild taxa.

Hybridization among diploid species of *Aegilops* gave rise to amphidiploids. These tetraploid taxa are colonizers and have introgressively hybridized to form mixed populations which are aggressive weeds in disturbed areas and roadsides. All of the tetraploids share a common pivotal genome from *A. umbellulata.* The other portions of their genomes came from one of seven other species. The hybrid plants created by tetraploid X diploid crossings are low in fertility. Seed set in these plants is due primarily to pollen from open pollinating parental (diploid) taxa. Progeny of these plants regain fertility in one or two generations. Pazy and Zohary (1965) and Feldman (1965) presented cytogenetic hybridization, and field analyses data to support this. Three of the species they investigated in Turkey, Greece and Israel are also introduced grasses in the U.S. flora. The question arises whether this same phenomenon is occurring in the United States.

Wild-Weed-Crop Complexes

Weeds are associated with man's diverse endeavors. Many weeds have originated from the same complexes that spawned crops. This is not surprising since the same adaptations required of many crops make good weedy attributes as well. These characteristics all involve adaptations to disturbed habitats. Most annual (if not all) crops have weed forms that are recognized as conspecific, subspecific, or as a closely related species. These include: *Phleum pratense* (Timothy), *Cynodon dactylon* (Bermuda grass), *Pennisetum clandestinum* (Kikuyu grass), *Lotus corniculatus* (bird's foot treefoil), *Daucus carrota* (Carrot), *Pastinaces sativa* (parsnip), *Cannabis sativa* (Marihuana), *Oryza sativa* (rice), *Ricinis cummunis* (castor bean), *Coix lacryma-jobi* (Job's tears), *Echinochloa crusgalli* (barnyard millet), *Helianthus annum* (sunflower), *Chicorium intybus* (chickory), *Avena sativa* (oats, once a weed in Emmer fields), *Sorghum halepense* (Johnson grass), and *Rhaphinus sativa* (radish). This list is by no means complete but serves to illustrate the diversity of genera in which this occurs. Harlan (1965) lists other weed races of cultivated plants. The question that these data begs is how much genetic change is required to complete the transition from weed to crop or from crop to weed and what is the qualatative nature of this change?

Weediness has also originated by introgression of wild and crop taxa. *Glycine gracilis* is a weedy member of the soybean group of *Glycine.* Its putative origin is the hybridization of *G. ussuriensis* with cultivated *G. max* (Hymowitz, 1970). *Solanum sparsipilum* is a weed member of the potato genus and originated through hybridization of the crop (*S. tuberosum*) with one of three wild taxa as discussed by Ungent (1970). Weed sorghums have evolved as hybridization products of cultivated *Sorghum bicolor* and wild taxa (de Wet et al, 1970). *Rhaphinus raphinestrum* (Panetos and Baker, 1967), a weed, has by introgression with *R. sativa* created a weedy race of *R. sativa. Latuca serriola* (weed lettuce) possibly owes its weediness to genes of *L. sativa* (Lindquist, 1960). A new weed recently noticed in Illinois called "bigweed" or "jolly green giant" might have originated from introgression between *Setaria viridis* and *S. italica* (millet). This possibility is currently being investigated at the Crop Evolution Laboratory.

Nearly every crop has associated with it a weedy and a wild relative. Gene exchange in any combination among weed, wild and crop taxa can

create weediness. Few of the wild and weed taxa related to crops have been investigated in any detail and therefore the origins of our most important crops and weeds remain obscure.

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ECOLOGICAL INTERPRETATIONS OF THE VEGETATION PATTERNS OF VOLO BOG, LAKE COUNTY, ILLINOIS

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ABSTRACT.—The vegetation patterns of a sphagnum bog in northeastern Illinois were studied. Quantitative data were collected on cover, density and basal area of woody plants and cover of herbs along transects through all vegetation types. Five primary and two minor vegetation types were delineated. A floating mat composed of herbs and mosses surrounded and advanced on an open pool. Shrubs and then tamaracks invaded the mat. Shrubs present with the tamaracks persisted indefinitely while the tamaracks failed to reproduce, giving rise to an extensive secondary shrub community beyond the coniferous forest. Evidence for transition of the tamarack forest or secondary shrub vegetation to mesophytic forest, as reported in the literature, was not observed. The two minor vegetation types, aspen groves and parklands of poison sumac, did show a closer relationship to surrounding mesic vegetation, but appeared to be edaphically rather than successionally determined.

The Woodfordian Substage of the Wisconsinan glaciation produced the Valparaiso Moraine, a prominent upland complex encircling the southern end of Lake Michigan. In western Lake County and eastern McHenry County, Illinois, and adjacent areas, this moraine is composed of much waterworked sand and gravel and is marked by an abundance of kettles. These depressions are occupied by lakes, bogs and marshes. One of the most biologically interesting of these areas is Volo (Sayer) Bog. This bog

FIGURE 1.—Aerial view of bog from south.

is two miles northwest of Volo, Lake County, in the NE ¼ Section 28, T. 45 N., R. 9 E. of the Grays Lake Quadrangle. The bog is under the auspices of the Illinois Nature Preserves Commission and the State Department of Conservation.

Volo Bog (Fig. 1) first was described by Waterman (1921, 1923, 1926) and since has been used widely for research and as a resource area for professional and amateur naturalists. Classical bog succession, as described by Whitford (1901), Transeau (1903, 1905), Dachnowski (1912), Cooper (1913), and others, is graphically illustrated in parts of Volo Bog. Despite intensive use of this bog, the vegetation is described only superficially. No quantitative vegetation analysis is available.

The authors' familiarity with the bog, spanning a period of several years, and the study described here give rise to a more complete and somewhat different description and interpretation of vegetation than previous studies by Waterman (1921, 1923, 1926), Kurz (1928), Reichle and Doyle (1965), and Reichle (1969). Because striking vegetation changes have occurred since Waterman's studies and increasing disturbance and development of the surrounding area threaten to further alter conditions in the bog, it is important that information be summarized at this time. Our study, in addition to providing a detailed analysis of a bog, indicates trends in bog succession not generally suggested in the literature.

General Description

Volo Bog occupies a reniform depression oriented nearly north and south between prominent till ridges. The depression consists of two basins (Artist, 1936). The smaller northern basin is completely peat-filled; the larger southern basin still exhibits a small area of open water. It is the southern basin that so prominently displays successional zones. Hydrarch bog succession is well described (e.g. Whitford, 1901; Transeau, 1903, 1905; Cooper, 1913; Dachnowski, 1912, 1924; Dansereau and Segadas-Vianna, 1952), and we do not attempt to review it here. The vegetation patterns exemplified in Volo Bog should be familiar, at least in part, to most students of ecology.

The southern basin exhibits five primary vegetation types and two minor types. The open pool, approximately 40 m. long by 25 m. wide (Fig. 2), is surrounded by a floating mat varying from a few to 60 m. in width. Invading the mat is a shrub community, which in turn is replaced by a tamarack (*Larix laricina* (DuRoi) K. Koch.) forest. Surrounding this forest is a second, more extensive shrub community. These bog associations abruptly give way to a marsh at the periphery of the depression. These five vegetation types occur in roughly concentric zones around the central pool. Scattered irregularly in the edge of the outer shrub community are two less extensive but significant communities, one dominated by poison sumac (*Rhus vernix L.*) and the other by quaking aspen (*Populus tremuloides* Michx).

The substrate in the southern basin is a layer of Sphagnum peat less than one meter in thickness overlying Carex peat (Artist, 1936). Live Sphagnum is abundant at the surface. In the northern basin, however, Sphagnum is greatly restricted and the surface layer is largely woody peat greater than two meters in thickness; Carex peat also occurs under the woody peat (Artist, 1936).

Vegetation of the two basins is similar in aspect, although details of composition differ. Succession in the northern basin evidently is much farther advanced; the open pool as well as the herb mat vegetation is absent. Tamaracks in the northern

basin were cut prior to Waterman's first study (1921). Furthermore, *Rhamnus fragula* L., an Eurasian species naturalized in eastern United States, has obliterated virtually all of the original vegetation patterns except the second-growth tamaracks. For these reasons, it is difficult to determine the successional patterns. Presence of woody peat further complicates interpretation. A brief description is included, however, be-

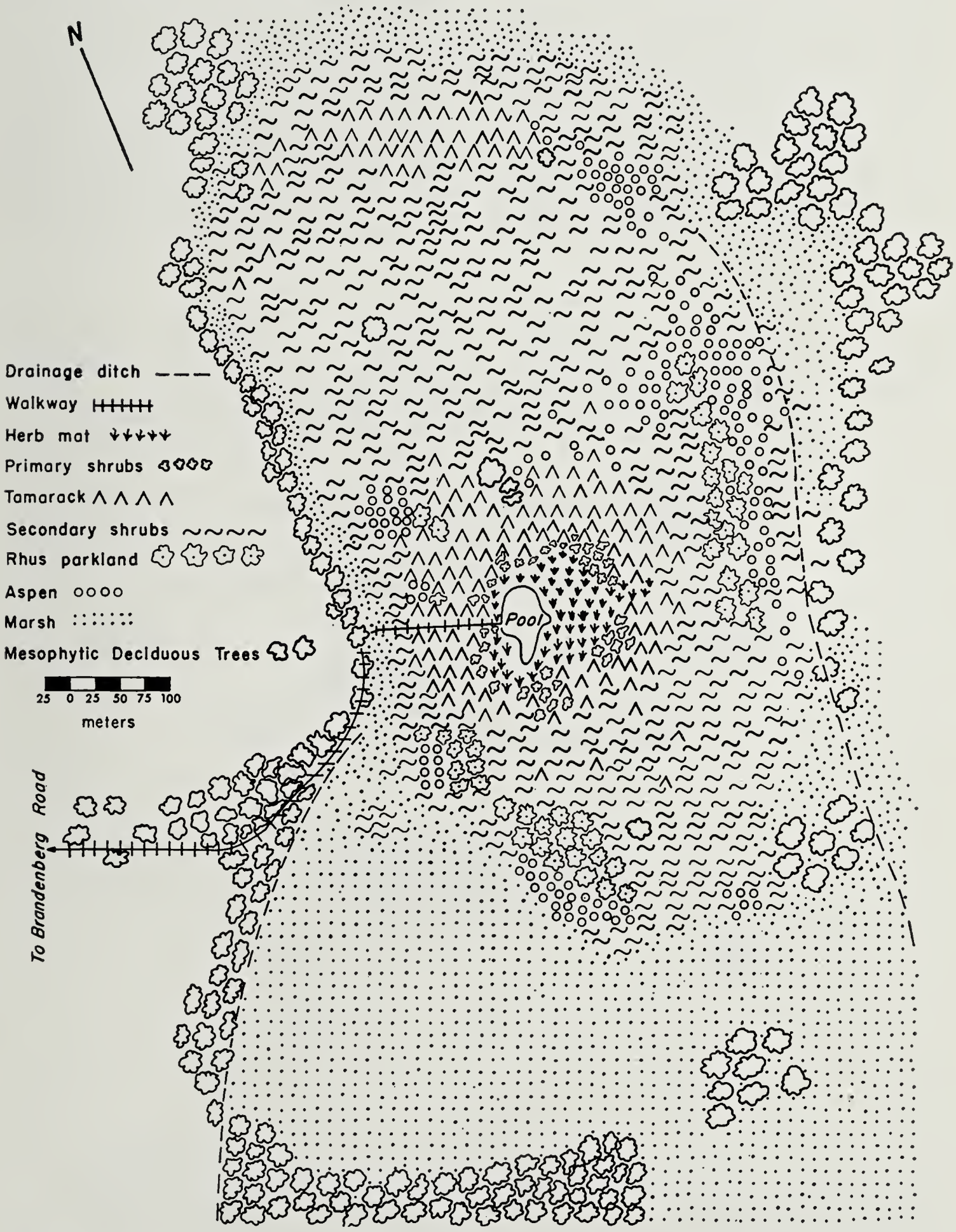

FIGURE 2.—Schematic interpretation of vegetation of Volo Bog.

cause some conclusions are supported by patterns in the northern basin.

Methods

The bog was visited frequently over the past several years during which time concepts and ideas were formulated. Before undertaking the intensive study, aerial reconnaissance was flown in May 1971. By use of aerial photos and information gained from earlier ground reconnaissance, transects were established along compass lines from the central pool outward to the periphery of the bog to include all sections of the bog and all vegetation types. Vegetation in the pool and upland forest was not sampled. Data were collected 24-27 June 1971 along four primary transects that totaled 1040 m. in length. Representative specimens of plants were collected in June and in September and are deposited in the Herbarium of the University of Illinois.

Trees and shrubs were sampled with continuous one meter wide strip transects. For statistical analyses and convenience in recording data, strips were broken at 10 m. in-

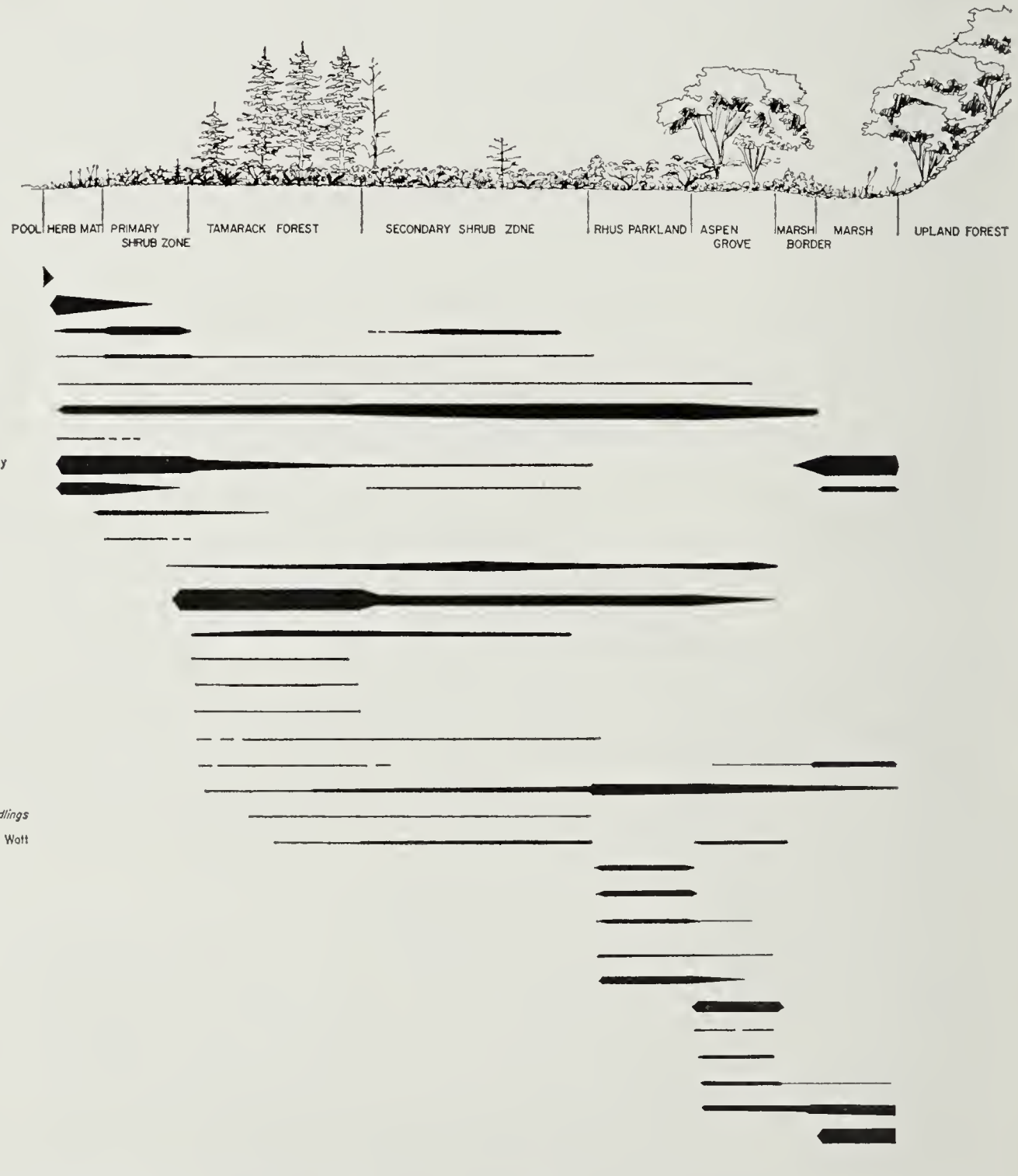

FIGURE 3.—Distribution (horizontal axis) and relative importance (vertical axis), based on cover and frequency, of herbs in Volo Bog with mean cover greater than one percent in the vegetation type where the species most frequently occurred.

tervals. Density of shrubs was based on clump tallies. Cover was estimated by line intercept along one edge of the strip. Diameters of all trees greater than 2.5 cm. dbh were measured. Herbs were sampled at 5 and 10 m. intervals along the transects, frequency of sampling being determined by uniformity and extent of the community. Cover for herb species was visually estimated in ½ x ½ m. quadrats. The stoloniferous growth form of most herbaceous species negated the significance of density; therefore, counts were not made.

Based on the data and field observations, data were compiled and statistically analyzed according to vegetation types. Data from plots falling on transitions were examined separately.

Vegetation Analysis

Figure 3 diagrammatically presents the distribution (horizontal axis) and relative importance (vertical axis) of all herbaceous species which occur with mean cover greater than one percent in at least one community. Woody species (Fig. 4) necessarily are graphed on a different arbitrary importance scale. The diagram in

Figure 4.—Distribution (horizontal axis) and relative importance (vertical axis), based on cover, frequency and basal area, of woody plants in Volo Bog with mean cover greater than one percent in the vegetation type where the species most frequently occurred.

TABLE 1.—Species observed or sampled, having less than one percent cover for their indicated habitat.

Species	Herb mat	Primary shrubs	Tamarack	Secondary shrubs	Rhus parkland	Aspen	Marsh
Sparganium eurycarpum Engelm.	*						
Scripus cyperinus (L.) Kunth	*						
Eriophorum angustifolium Nutt.	*						
Glyceria striata (Michx.) Trin.	*						
Calamagrostis canadensis (Michx.) Beauv.	*						
Galium tinctorium L.	*						
Polygonum punctatum Ell.	*						
Epilobium leptophyllum Raf.	*						
Oxypolis rigidior (L.) Raf.	*						
Phragmites communis Trin.	*	*					
Triadenum fraseri (Spach) Gleason	*	*					
Lycopus americanus Muhl.	*	*					
Rumex verticillatus L.	*	*					
Pogonia ophioglossoides (L.) Ker.	*	*					
Carex lasiocarpa Ehrh.	*	*					
Lysimachia thyrsiflora L.	*	*					
Liparis loeselii (L.) Rich.	*	*	*	*			
Equisetum fluviatile L.	*	*	*	*			
Viola pallens (Banks) Brainerd	*	*	*	*	*		
Scutellaria galericulata L.	*	*		*			*
Stellaria longifolia Muhl.	*			*			
Aster junciformis Rydb.	*			*			
Agrostis hyemalis (Walt.) BSP.		*					
Salix candida Fluegge		*					
Carex leptalea Wahl.		*					
Dulichium arundinaceum (L.) Britt.		*					
Scleria sp.		*					
Oxycoccus macrocarpus (Ait.) Pursh.	*	*					
Vaccinium corymbosum L.	*	*					
Sarracenia purpurea L.	*	*					
Drosera rotundifolia L.	*	*					
Eupatorium perfoliatum L.	*	*					
Habenaria lacera (Michx.) Lodd.	*	*		*			
Eleocharis palustris (L.) R. & S.		*					
Monotropa uniflora L.		*					
Lycopodium lucidulum Michx.		*		*			
Dryopteris crista (L.) A. Gray		*		*			
Betula purpusii Schneid.		*		*			
Maianthemum candense var. interius Fern.		*		*			
Caltha palustris L.		*		*			
Aralia nudicaulis L.		*		*			
Saxifraga pennsylvanica L.		*		*	*		
Smilacina racemosa (L.) Desf.		*			*		
Acer saccharinum L.				*			
Corylus americana Walt. (1 plant)				*			
Taraxacum officinale Wiggers				*			
Pilea fontana (Lunell) Rydb.				*	*		*
Eupatorium purpureum L.				*			*
Solidago gigantea Ait.					*		
Asclepias incarnata L.					*		
Polygonum sagittatum L.					*		
Cuscuta campestris Yuncker					*		
Geum canadense Jacq.					*		
Salix nigra Marsh					*		
Smilax lasioneura Hook.					*	*	
Lactuca biennis (Moench) Fern.					*	*	
Acer negundo L.					*	*	
Betula papyrifera Marsh.						*	
Betula lutea Michx. f.						*	
Lobelia siphilitica L.						*	
Cicuta bulbifera L.						*	
Echinocystis lobata (Michx.) T. & G.						*	*

these figures represents an idealized cross section of the southern basin of the bog along one radius from the central pool. All data for each community were combined for analysis and interpretation. All other species observed or sampled are listed in Table 1.

As can be seen from Figures 3 and 4 and Table 1, the floating mat is composed of many herbaceous species with a few scattered shrubs and tamaracks invading in the older portions. The mat consists of a matrix of roots and mosses, especially *Sphagnum recurvum* Beauv. (Reichle and Doyle, 1965; Reichle, 1969). *Eleocharis calva* Torr. initiates mat formation. Away from the pool, several species assume importance. Dominant species include *Carex hystricina* Muhl., *Dryopteris thelypteris* (L.) A. Gray, *Typha latifolia* L., and *Onoclea sensibilis* L.

Invading the outer portion of the herb mat is a shrub community of *Rhus vernix, Betula pumila* L., and *Chamaedaphne calyculata* (L.) Moench. Of lesser importance are *Salix discolor* Muhl., *S. bebbiana* Sarg., and *S. pedicellaris* Pursh. This shrub zone is narrow, irregular, and in places poorly defined or absent. Although the herbaceous species are primarily those of the herb mat, *Menyanthes trifoliata* L. and *Potentilla palustris* (L.) Scop. reach their peak abundance in this shrub zone. We designated this community the "primary shrub zone" to distinguish it from the secondary shrub community occurring successionally and geographically after the tamarack forest.

Beyond the shrubs, and sparsely invading them, is a forest of tamarack with a much firmer peat substrate. Tamarack commonly occurs in pure stands with a shrub layer of *Ilex verticillata* (L.) A. Gray, *Rhus vernix,* and *Rhamnus frangula.* Although the arboreal aspect of the community is wholly tamarack in most portions of the forest, along the western margin tamaracks become mixed with *Betula purpusii* Schneid. or locally yield to *Betula lutea* Michx. f., *B. papyrifera* Marsh., or *Populus tremuloides.* Of the herbs present, *Osmunda cinnamonea* L. is of greatest importance with *Onoclea sensibilis, Trientalis borealis* Raf., and *Carex trisperma* Dewey as significant associates.

Outside the tamarack forest is the secondary shrub zone composed primarily of the three shrub species in the forest. Tamaracks gradually become less abundant in the transition from the forest to the shrub community, but in places the tamaracks abruptly give way to the secondary shrubs. *Betula lutea, Populus tremuloides,* and occasionally *Betula papyrifera* intervene in the transition in a few isolated areas along the northern boundary of the forest. Many dead tamaracks, both standing and fallen, are present in the secondary shrubs. Important herbs in the secondary shrub community include *Potentilla palustris, Onoclea sensibilis,* and *Osmunda cinnamomea.*

The bog is surrounded by a marsh, nearly absent in places, but generally moat-like, and expanding to occupy the southern quarter of the depression (Fig. 2). Principal species are *Phalaris arundinacea* L., *Solanum dulcamera* L., *Typha latifolia, Dryopteris thelypteris,* and *Poa palustris* L., with *Betula pumila* and *Spiraea alba* DuRoi of importance in the southern marsh near the shrub zone.

The transition between the shrub and marsh communities varies. Often it is abrupt, marked by a dense growth of unusually large *Ilex verticillata.* This winterberry thicket comprises an almost continuous zone around the bog. In a few areas, a totally distinct community intervenes between the dense winterberry growth and the marsh. The aspect of this com-

munity is a parkland of regularly scattered *Rhus vernix* shrubs and trees of unusually large size. The understory consists of *Sambucus canadensis* L., *Cornus obliqua* Raf., *Geum canadense* Jacq., *Urtica gracilis* Ait., *Smilacina stellata* (L.) Desf., *Lactuca biennis* (Moench) Fern., *Solidago gigantea* Ait., and other mesophytic species. The *Rhus* parkland usually is separated from the marsh by groves of *Populus tremuloides.* Associated with aspen in the groves are *Rhus vernix, Cornus obliqua, Ambrosia trifida* L. and *Arabis laevigata* (Muhl.) Poir. Both the aspen groves and the *Rhus* parkland contain species present in other bog communities, but there is a prevalence of mesophytic and wet mesophytic species as opposed to the more typical bog plants. The bog plants that do occur are those of apparently wide ecological amplitude. such as *Rhus vernix, Osmunda cinnamomea,* and *Onoclea sensibilis. Acer negundo* L. is widely scattered in these communities, increasing in frequency in the aspen groves.

Two separate and distinct tamarack forests are present in Volo Bog (Fig. 1). The northern forest is on woody peat and is separated from the southern forest, described above, by a shrub zone composed primarily of *Rhamnus frangula.* In a very restricted open area on the northern edge of the north forest, a surface layer of appressed, slow growing Sphagnum is present. A dense to scattered growth of *Chamaedaphne calyculata,* with less frequent *Vaccinium corymbosum* L. forms a shrub zone without noticeable herbaceous associates in this Sphagnum area. The tamarack forest, composed only of tamaracks with an understory of *Rhamnus,* is invading this shrub community. *Rhamnus* apparently has invaded and replaced much of the original community in the northern basin; it now forms an exclusive shrub community consisting only of very large, often tree-like shrubs and a few herbaceous species, especially *Dryopteris spinulosa* (O. *F.* Muell.) Watt. Waterman (1921) indicated the presence of other shrub species in this area, especially *Vaccinium corymbosum,* but *Rhamnus* was not mentioned in his papers. Ring counts of *Rhamnus* in this area indicate that many plants, at least, were present during Waterman's studies. Therefore, the possibility of misidentification on his part must be considered and the nature of the original community in this area is thus not known. This *Rhamnus* community corresponds with the limits of woody peat distribution, as apparently some former community once did.

Successional Processes

Classical hydrarch succession is clearly evident around the pool in the southern basin. The floating mat is advancing on the open water and, based upon photographs, has encroached perhaps one or two meters since Waterman's studies (1923). Waterman (1923, 1926) noted that the pool had occupied nearly all of the area surrounded by tamaracks as late as about 1870, and that the mat had invaded since that time.

This rapid development of the mat probably explains the distribution of *Chamaedaphne calyculata* around the pool. This species is almost totally restricted to one small heath-like area surrounded on three sides by tamarack. It otherwise occurs only as a narrow fringe along some portions of the tamarack forest. *Chamaedaphne* probably marks the extent of the mat before the period of rapid expansion. This shrub has been unable to invade the newly developed portions of the mat, which apparently remain unsuitable for the species for reasons not known to us. Other shrub species are invading the mat, judging from the distribution of individuals of the component species. Consequently, the

primary shrub zone, except for the limited area described above, is not of the typical *Chamaedaphne* type generally described in the literature.

Regardless of the composition of the primary shrub zone, tamaracks obviously invade this community. Tamarack saplings occur in virtually all portions of the primary shrub zone, albeit infrequently, with the possible exception of areas of dense *Betula pumila*. With establishment of the tamarack forest, *Rhamnus* and *Ilex* appear. *Rhus* persists and increases in size (See Fig. 5).

With the decrease in density of the tamaracks with age of the forest, the subordinate shrubs became dominant and form the secondary shrub community (See Fig. 6). Since this community is the most extensive vegetation type in the bog, it is curious that earlier workers have failed to recognize it. Dachnowski (1912)

FIGURE 6.—Winter view of secondary shrub community from elevated position.

FIGURE 5.—Summer view across central pool showing herb mat, primary shrub zone and tamarack forest.

FIGURE 7.—Winter view of tamarack forest showing dense understory of shrubs.

described similar zones but ignored them in his interpretations of succession. Although frequently mentioning shrub zones around bogs in northeastern Illinois, Waterman similarly ignored them. Waterman (1921, 1923, 1926) further indicated that the entire area here interpreted as secondary shrub zone was tamarack forest, yet his photograph (1921) clearly shows a prominent shrub zone, much greater in extent than his term "border" implied. Kurz (1928) supplied a cross sectional diagram of Volo Bog also omitting this zone. The best description of the bog is provided by Reichle (1969), but he too ignored the secondary shrub zone and indicated a transition between the tamarack forest and the mesophytic forests of the uplands. We see little evidence for such a transition.

Transeau (1903, 1906) repeatedly emphasized that the bogs in southern Michigan and northern Indiana were in no way related to the surrounding oak-hickory forests, and that succession from bog mat to mesophytic forest did not occur. This is clearly the case at Volo and other nearby bogs, but apparently has been overlooked by other local workers. The dense growth of shrub species and *Osmunda cinnamomea* in the older portions of the tamarack forest (Fig. 7) preclude general reproduction of tamarack, and with the death of older trees the shrubs assume dominance. This process probably has been enhanced greatly by the invasion of *Rhamnus*. The presence of *Rhamnus* may explain, at least partially, the loss of the scattered tamaracks between the two present forests, although the actual cause of death of the older trees is not definitely discernable, as discussed later. In typical secondary shrub zone, as in the southern basin, tamaracks are very scattered and young trees are rare. This situation probably is representative of natural conditions although it seems likely that without the presence of *Rhamnus,* tamarack reproduction would be somewhat greater throughout the secondary shrub zone. This meager reproduction would be sufficient to maintain the forest as present in Waterman's time. In the northern basin, with the dense growth of *Rhamnus,* tamarack reproduction is absent. Even in the more natural secondary shrub zone of the southern basin, tamarack reproduction declines and eventually ceases as the shrubs mature and the community becomes more dense.

The invasion of *Rhamnus* raises the question of concurrent disturbance. As mentioned previously, the northern basin was cut over, and the associated vegetation has been replaced almost totally by *Rhamnus*. In addition to *Rhamnus* invasion, drainage may be a factor. Two drainage ditches are present on the periphery of the bog. Their effectiveness appears to be very local. The loss of

tamaracks in the secondary shrubs of the northern basin and their decline in the southern basin evidently was abrupt, judged by the abundance of dead trees in approximately the same degree of decomposition. Perhaps the decline of the tamaracks in the shrub communities was influenced by drainage, although there is no evidence that the tamarack forest suffered much loss. Waterman (1926) believed a regional lowering of the water table was responsible for the general demise of the bogs in this area. The combined effects of moisture stress and the activity of bark beetles may have been responsible. Shelford (1963) reported heavy damage to the tamaracks of Volo Bog resulting from an outbreak of these insects about 1942, and many of the dead tamaracks exhibit bark beetle damage.

Although drainage, bark beetles, and invasion of *Rhamnus* may account for the loss of tamarack in the secondary shrub zone, the trees originally were very scattered and we do not consider the secondary shrub zone itself to be a product of disturbance. Undrained and little disturbed bogs in this area exhibit a similar shrub pattern.

Transeau (1905) described vegetation communities similar to the secondary shrubs but suggested that they always resulted from cutting of the tamaracks. Such was not the case at Volo Bog. Waterman (1921, 1923, 1926) reported that only the forest in the north end of the northern basin was cut. This area since has been repopulated by tamaracks. The evidence indicates that the secondary shrub zone at Volo Bog, and doubtless comparable zones in other bogs in this area, is a natural successional stage resulting from inhibition of tamarack reproduction through competition with the shrubs which become established in the tamarack forests. No direct succession from tamarack forest to mesophytic forest occurs. The presence of *Acer negundo, Populus tremuloides, Betula papyrifera, B. lutea,* and *B. purpusii* should not be construed as general mesophytic invasion as discussed later. A few individuals of *Acer saccarinum* L. were encountered in the bog and, although indicating that succession may eventually lead to mesophytic forest, they were so infrequent as to indicate no general invasion of mesophytic forest as occurs in the Northeast. The secondary shrub zone is a community of great stability, as stated by Transeau (1905), and appears to behave as a long-lasting subclimax. This is further emphasized by conditions in the northern end of the bog. Transeau (1905) stated that cutting or drainage of tamarack bogs may initiate wet-mesophytic invasion. Yet in Volo Bog, the cut-over northern portion of the bog, exhibiting a relatively drier woody peat, has grown back to bog vegetation. The *Rhamnus* forest, although an unnatural bog community, invaded long after the initial disturbance and must have eliminated another bog community. Mesophytic invasion had not occurred at the time of *Rhamnus* establishment, nor has mesophytic invasion yet occurred. The northern end of the bog, under conditions most favorable for mesophytic invasion, supports only a few widely scattered *Prunus serotina* Ehrh. and *Quercus rubra* L., usually growing near the border of the marsh.

Some quaking aspen occurs as scattered trees and one grove in the secondary shrub zone between the southern tamarack forest and the *Rhamnus* forest in the north (Fig. 1). Major development of the species is in scattered groves between the bog and marsh communities (See Fig. 8). According to Dachnowski (1912), quaking aspen in Ohio bogs is confined to areas of shallow or mineral-rich peat, a conclusion sup-

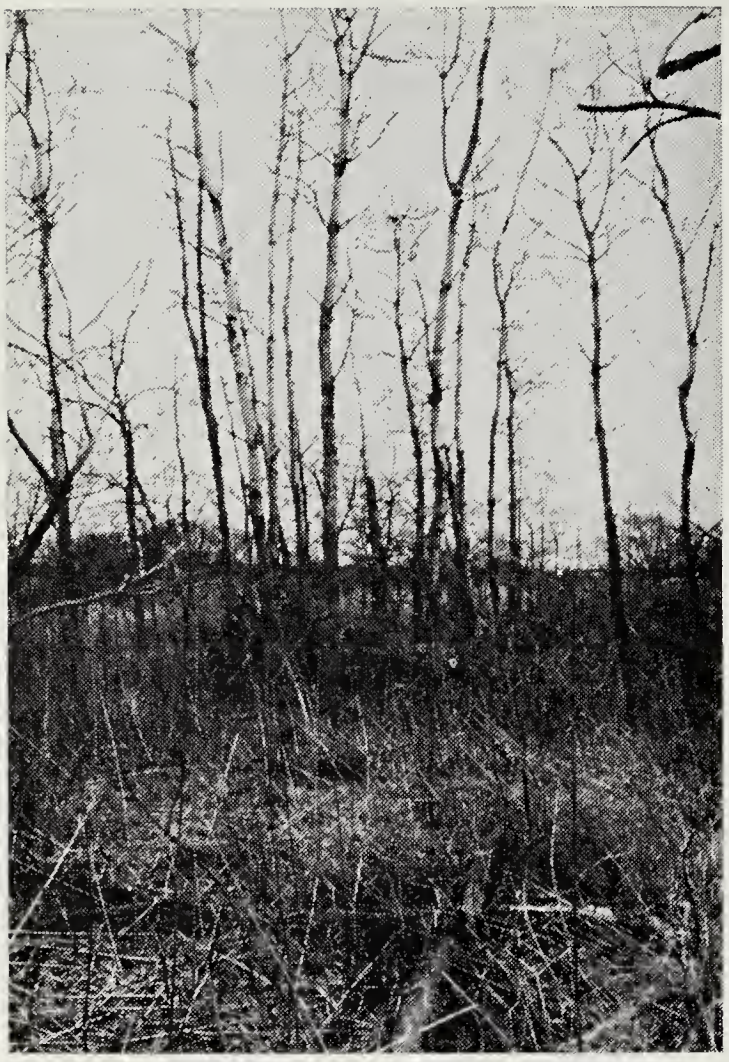

FIGURE 8.—Autumnal view of aspen grove from adjacent *Rhus* parkland.

ported by the high pH (averaging 5.9) of aspen soils at Volo. This is in sharp contrast to the tamarack and secondary shrub communities, where soils range from pH 3.1 to 4.9. This explains the peripheral locations of the groves and also the east-west extension of scattered trees between the southern tamarack forest and northern *Rhamnus*-dominated shrub zone. The location of groves on the periphery of the bog communities and immediately adjacent to the marsh reflects proximity to the calcareous, base-rich till of the uplands and drainage derived from it. Artist (1936) indicated a till ridge extending to within less than two meters of the surface of the bog in the general area of east-west aspen extension. This ridge evidently supplies sufficient mineral infusion of the peat to support the aspen. Therefore, it appears that quaking aspen bears no direct successional relationship to the other bog vegetation but rather occurs in response to local edaphic conditions.

The distribution of *Betula lutea, B. papyrifera,* and *B. purpusii* appears to be similarly based. All occur in the region of east-west aspen extension. *Betula purpusii* reflects its hybrid ancestry (*(B. lutea* x *B. pumila)* by ranging rather widely from this area, with one plant in the primary shrub zone, although the behavior of the hybrid is most like that of *B. lutea.*

The *Rhus* parkland (Fig. 9) has a consistent relationship to the aspen groves, always occurring between the aspen and the secondary shrub zone. A zone of unusually large *Ilex* separates the secondary shrub zone from the *Rhus* parklands. The significance of these parklands is obscure. They may represent, like the aspen groves, a segregation of species in response to local edaphic conditions, as is indicated by the pH of parkland soils (averaging 5.8). Aspens appear to invade only rarely the periphery of the parklands. The herbaceous and shrub synusia of both the parkland and aspen groves are quite distinct, although both are markedly mesophytic. Along the western margin of the southern tamarack forest, in an area of compressed zonation, an embryonic *Rhus* parkland occurs in the mature tamarack forest. The adjacent secondary shrub zone supports scattered aspen. This parkland is clearly originating within the tamarack forest although it may not be a component of the forest, but rather an independdent community formed at the time of primary shrub and tamarack invasion. The adjacent aspen grove, however, is invading the secondary shrub zone. Thus these two vegetation types may originate under different successional regimes, resulting in different floras. This also explains the lack of aspen invasion of the *Rhus* parkland; they are not successionally

FIGURE 9.—Autumnal view of *Rhus* parkland with typical, widely spaced, large poison sumacs.

related. It appears that the *Rhus* and aspen vegetation manifest different responses along an edaphic gradient, probably reflected by base saturation of the peat.

The *Rhus* parkland and aspen groves exhibit evidence of succession toward more mesophytic species. This especially is evident with *Acer negundo* invasion. Many dead aspen and *Rhus* are present in these communities but vegetative reproduction is continuing under the very open canopies. It is difficult to estimate how persistent these communities will be, but the sharp transition between secondary shrub communities and the *Rhus* parkland suggests a very stable relationship.

CONCLUSIONS

Vegetation of Volo Bog, generally considered to represent classical hydrarch bog succession, was intensively studied. Two basins are easily discernable from the vegetation patterns. Primary attention is given to the southern basin which most clearly exhibits the successional processes. Vegetation was classified into five primary types in roughly concentric zones around the open pool and two minor vegetation types scattered irregularly between the two outer zones. The pool is surrounded by an herb mat, giving way irregularly to a primary shrub community that is invaded by a tamarack forest. The tamarack forest is replaced by a long-persisting secondary shrub community. Girdling the secondary shrub vegetation is a marsh. The secondary shrub-marsh ecotone is irregularly interrupted by development on more mineralized peat of the minor *Rhus* parkland and quaking aspen vegetation types.

Our studies lead us to conclude that striking changes have occurred in the secondary shrub communities since Waterman (1921, 1923, 1926) first described the area. Most of the secondary shrub constituents, including scattered tamaracks, have been replaced in the northern basin by *Rhamnus frangula*. *Rhamnus* also has become a dominant species in the secondary shrub community in the southern basin and in tamarack forests and may be hastening the replacement of tamarack by shrub species. Demise of tamarack also may have been influenced by lowering of the watertable and a bark-beetle outbreak.

No evidence could be found for succession leading to mesophytic forest, except on small areas of mineral-rich peat. With exception of the *Rhamnus* invasion, the secondary shrub community appeared to be stable with shrub species reproducing throughout.

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NOTES

HUSBANDRY PRACTICES FOR RANA PIPIENS FROGS THAT INFLUENCE HUMAN PREGNANCY TESTING

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ABSTRACT.—The success of the *Rana pipiens* male frog test for human pregnancy depends on specifying that the test frogs be held at low temperature, 5° C in these experiments.

Immunologic tests for human pregnancy involving detection of gonadotropin (Taylor, 1965; Greenhill, 1966) have been rapidly replacing biologic tests. In the frog test, the major responsible factor for its increasing discontinuance has involved the question of its reliability. Because the newer latex-antigen pregnancy testing might in some cases be influenced by drugs and disease, biologic testing is worthy of standby use. We have found that the *Rana pipiens* male frog can be a uniformly successful animal model for pregnancy testing if more specification of environmental factors, as noted below, is observed.

Of 65 male frogs held at 5° C for 10 days without feeding and injected with 3 to 5 ml of clean concentrated urine from women in 3 to 6 months of pregnancy, the frogs then being catheterized via the cloaca to check for an expected emission of their sperm, there were 64 true positive results and 1 false negative. Of 70 frogs held at 25°-27° C for 10 days with feeding, only 25 showed true positive results. Of 82 frogs held at 25°-27° C without feeding, only 38 showed true positive results. The difference between warm, fed and warm, unfed frogs was not significant ($p < .16$). Non-feeding frogs in the cold were significantly different from the other groups ($p < .001$).

Moderate warmth in the frog somehow depresses testicular function or responsiveness to gonadotropic agents. Withholding of food for 10 days does not produce any gonadal depression. As a general conclusion, temperature appears to be a particularly important factor in determining the usefulness of the frog as an animal model for certain testing.

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SEASONAL TRENDS IN THE UTILIZATION OF MAJOR FOOD GROUPS BY THE RED FOX (*VULPES FULVA*) IN UNION COUNTY, ILLINOIS

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ABSTRACT.—Red fox foods exhibited variation in volume and occurrence with season. Animal foods were eaten in greater amounts during spring than other seasons. Marked differences in quantities of plant foods were noted between summer and fall and between winter and spring; higher amounts of plants were consumed in fall and winter than in the remaining seasons. Seasonal patterns in utilization of certain foods seem to be manifestations of seasonal availability of these items.

The only definitive analysis of food habits of the red fox (*Vulpes fulva*) in Illinois was presented by the author (Knable, 1970). The current paper is a supplement to the original work and is based on seasonal fluctuations in the foods of the red fox. For a discussion of the methods and materials used in the study, reference is made to Knable (1970). A total

of 183 red fox stomachs were examined of which 13 were empty or unproductive of data. Number of samples available according to season was as follows: summer, June-August (18); fall, September-November (32); winter, December-February (82); and spring, March-May (51). The summer months are least represented and contents of these samples may not be indicative of actual food habits.

Results and Discussion

Red fox foods exhibited variations in volume and occurrence with season (Table 1). Scott (1943), Scott and Klimstra (1955), and Korschgen (1957) also report seasonality of foods in the diet of the red fox. In general, seasonal patterns in utilization of major food groups were made apparent by volumetric comparisons; but for some food catagories (birds and arthropods) frequency of occurrence might be more indicative of seasonal use (Table 1).

Animal Foods

Animal materials, although the prominent source of food of the red fox in all seasons, showed significant seasonal differences in per cent by volume. Greater amounts of animal foods were recorded in spring than in any other season (Table 1). Mammalian foods were most heavily consumed in spring when most other foods were less available; but, in summer this food source was less important than in any other season. In fall and winter the proportions of mammalian foods in the diet were approximately equal. Scott and Klimstra (1955) report use of mammalian foods by the red fox highest in winter and lowest in summer.

Seasonal differences of avian foods showed the greatest variation in occurrence from spring to summer (Table 1). The sharp increase in occurrence of birds between spring and summer was probably a reflection of increased vulnerability of birds to predation in summer due to nesting and associated activities. Korschgen (1957) also reported the occurrence of avian food to be highest during summer. Volumetrically, summer represented the period of greatest use of avian foods.

Based on frequency of occurrence, consumption of arthropods tended to be more subject to changing seasons than other food groups. Arthropods, almost exclusively insects, were found in largest proportions in summer and fall and declined in winter and spring (Table 1); Scott (1943) and Korschgen (1957) found similar seasonal trends.

Plant Foods

Plants, excluding such items as grass and leaf, stem, and bark fragments, were utilized in greatest proportions in the fall diet of the red fox. Significant quantitative differences in the use of plant items were noted

Table 1.—Seasonal trends in utilization of major food groups by the red fox, Union County, Illinois, 1956-1967.[1]

Season	Mammals		Birds		Arthropods		Plants	
	Per cent volume	Per cent occurrence	Per cent volume	Per cent occurrence	Per cent volume	Per cent occurrence	Per cent volume	Per cent occurrence
Spring	92.2	100.0	2.4	14.9	0.2	27.7	4.6	97.8
Summer	37.1	86.7	43.2	33.3	11.6	93.3	6.3	93.3
Fall	61.7	96.9	0.2	21.9	4.2	68.8	31.1	100.0
Winter	65.0	92.1	8.6	31.6	T	6.6	26.1	96.1

[1]Items less than 0.1 per cent by volume designated as trace items (T).

between summer and fall and between winter and spring (Table 1). Scott (1943) also reported similar seasonal transitions in the proportions of plant food in red foxes. Greater amounts of plant foods were recorded in winter than in spring which was probably a reflection of the availability of frozen or dried fruits in winter.

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THE LEAST WEASEL, *MUSTELA NIVALIS*, IN WEST-CENTRAL ILLINOIS

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ABSTRACT.—The first record in west-central Illinois of *Mustela nivalis*, and a review of recent literature reporting southward range extensions of *Mustela nivalis* in the central and eastern United States are presented.

On March 13, 1971, a recently killed least weasel, *Mustela nivalis*, was found along a rural gravel road three miles NNW of Macomb, McDonough County, Illinois. Collection of this specimen is significant because it extends the known range of the least weasel into west-central Illinois. Closest previously reported occurrences to the McDonough County site are about 207 miles WSW at Stanberry, Gentry County, Missouri (Easterla, 1970); about 58 miles WNW at Mt. Pleasant, Henry County, Iowa (Hall, 1951); a minimum of 79 miles NNE somewhere within the area of Whiteside, Jo Daviess and Carroll counties, Illinois (Verts, 1960); about 109 miles NE at Henkel, Lee County, Illinois (Mohr, 1943); about 89 miles E near Normal, McLean County, Illinois (Schmidt and Lewin, 1968); about 134 miles ESE at Urbana, Champaign County, Illinois (Hoffmeister, 1956); and about 146 miles SSE near Columbia, Monroe County, Illinois (Parmalee, Bieri, and Mohrman, 1961). The Monroe County, Illinois report represents recovery of the lower jaw and the anterior half of a skull of a least weasel during excavation of a fissure fill in a Mississippi River bluff about four miles SW of Columbia; it was concluded that the specimen quite probably was a prehistoric occurrence (Parmalee and Munyer, 1966).

Collection of the McDonough County specimen reasonably extends the known range of the least weasel southwestward into most of an area

bounded by a line extending 114 miles ENE from Mt. Pleasant, Iowa to Henkel, Illinois, then 70 miles slightly SSE to Normal, Illinois, then 89 miles W to near Macomb, Illinois, and then 58 miles WNW back to Mt. Pleasant. Inclusion of this area as part of the range of *Mustela nivalis* on the range maps of Hall and Kelson (1959), and Burt and Grossenheider (1964) now appears completely justified.

Hoffmeister (1956) presented the then available information on the southern limits of the range of *Mustela nivalis* in the central United States. Since his review it has been reported for the first time from Kansas (Jones and Cortner, 1965), Missouri (Easterla, 1970), and Tennessee (Tuttle, 1968); southern extensions of range for the species have been reported for Indiana (Whitaker and Zimmerman, 1965), Iowa (Easterla, 1970), North Carolina (Barkalow, 1967), and Illinois (Parmalee and Munyer, 1966).

Other recent collections of the least weasel in Illinois which represent minor range extensions to the W in the center portion of the state are one specimen from Woodford County (Parmalee and Munyer, 1966) and 4 specimens from McLean County (Schmidt and Lewin, 1968). While not representing records of range extension, other recently reported collections of the least weasel in Illinois are 4 specimens from Champaign County (Parmalee and Munyer, 1966) and one from Kendall County (Calhoun, 1971).

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THE ACTIVATION ENERGY OF THE REACTION $H_2 + F \rightarrow H + HF$

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ABSTRACT: The London-Eyring-Polanyi-Sato (LEPS) and the modified London-Eyring-Polanyi-Sato (MLEPS) methods are used to calculate the activation energy of the reaction $H_2 + F \rightarrow H + HF$. It is found that the energy of activation calculated by MLEPS method is in much better agreement with the experimental result than by LEPS method.

Introduction

Extensive experimental results on the reaction $H_2 + F \rightarrow HF + H$ are not available because the reaction is so exothermic that it is difficult to control. Nevertheless Fettis and Knox (1964) have reported the energy of activation for the reaction to be 1.7 Kcal/mole, while Wilkins (1971) has reported the value to be 1.6 Kcal/mole. In the present work we apply both the London-Eyring-Polyanyi-Sato (LEPS) method and modified London - Eyring - Polanyi-Santo (MELPS) method to calculate the energy of activation of this reaction. The results obtained by the present calculation are compared with currently available data in the literature, as the relative merits of these two methods is discussed.

Theory and Calculations

The variation with interatomic distances of the potential energy E of a collinear three atom system XYZ can be readily calculated by the London equation (Glasstone, et al., 1941), $E = A + B + C - \{ \frac{1}{2} [(\alpha - \beta)^2 + (\beta - \gamma)^2 + (\gamma - \alpha)^2] \}^{\frac{1}{2}}$ (1) where A,B, C are the coulombic interactions of the pair of electrons on the atoms X and Y, Y and Z and Z and X, respectively, are α, β and γ are the corresponding exchange energies. The binding energy E_A of a diatomic molecule XY is dependent on the distance r between atoms, with reference to the energy of the separated atoms as zero; it is (Morse, 1929) $E_A = A + a = D_A [\exp(-2_A\rho_A) - 2\exp(-2_A\rho_A)]$ (2) where $\rho_A = r - r_{eA}$, D_A is the heat of dissociation of the molecule plus the zero point energy, r_{eA} is the equilibrium interatomic distance of the normal molecule and a_A is the Morse constant of the molecule. Eyring and Polanyi (Glasstone et al., 1941) suggested that the coulombic energies (A,B, and C) are a constant fraction (q) of the total binding energies, E, of the diatomic pair molecules XY, YZ and ZX. The q value usually ranges from 10 to 20%. Many activation energy calculations have been carried out by using this idea known as the London-Eyring-Polanyi (LEP) method. Sato (1955) modified the LEP method by introducing an anit-Morse function of the diatomic molecule XY.

$E_A^* = A - \alpha = D_A [\exp(-2a_A\rho_A) + 2\exp(-a_A\rho_A)]/2$ (3)

so that coulombic energy or exchange energy is no longer a constant fraction of the total binding energy but can be well defined with the help of equations (2) and (3) as a function of interatomic distance, r, as $A = D_A[\frac{3}{4}\exp(-2_A\rho_A) - \frac{1}{2}\exp(-a_A\rho_A)]$ (4)

$\alpha = D_A[\frac{1}{4}\exp(-2a_A\rho_A) - 3/2\exp(-a_A\rho_A)]$ (5)

This constitutes the London-Eyring-Polanyi-Sato (LEPS) method. Sato (1955) also offered an alternative method known as modified London-Eyring - Polanyi - Sato (MLEPS) method where A and a are calculated from the following equations:

$$E_A = \frac{A + a}{1 + Z_A} = D_A \left[\exp\left(-2a_{A\rho A}\right) - 2\exp\left(a_{A\rho A}\right)\right] \quad (6)$$

$$E_A^* = \frac{A - a}{1 - Z_A} = D_A \left[\exp\left(-2a_{A\rho A}\right) + 2\exp\left(-a_{A\rho A}\right)\right]/2 \quad (7)$$

where Z_A is the overlap energy of the molecule XY. Solving equations (6) and (7) we have,

$$A = D_A \left[(3 + Z_A)\exp\left(-2a_{A\rho A}\right) - 2(1 + 3Z_A)\exp\left(-a_{A\rho A}\right)\right]/4 \quad (8)$$

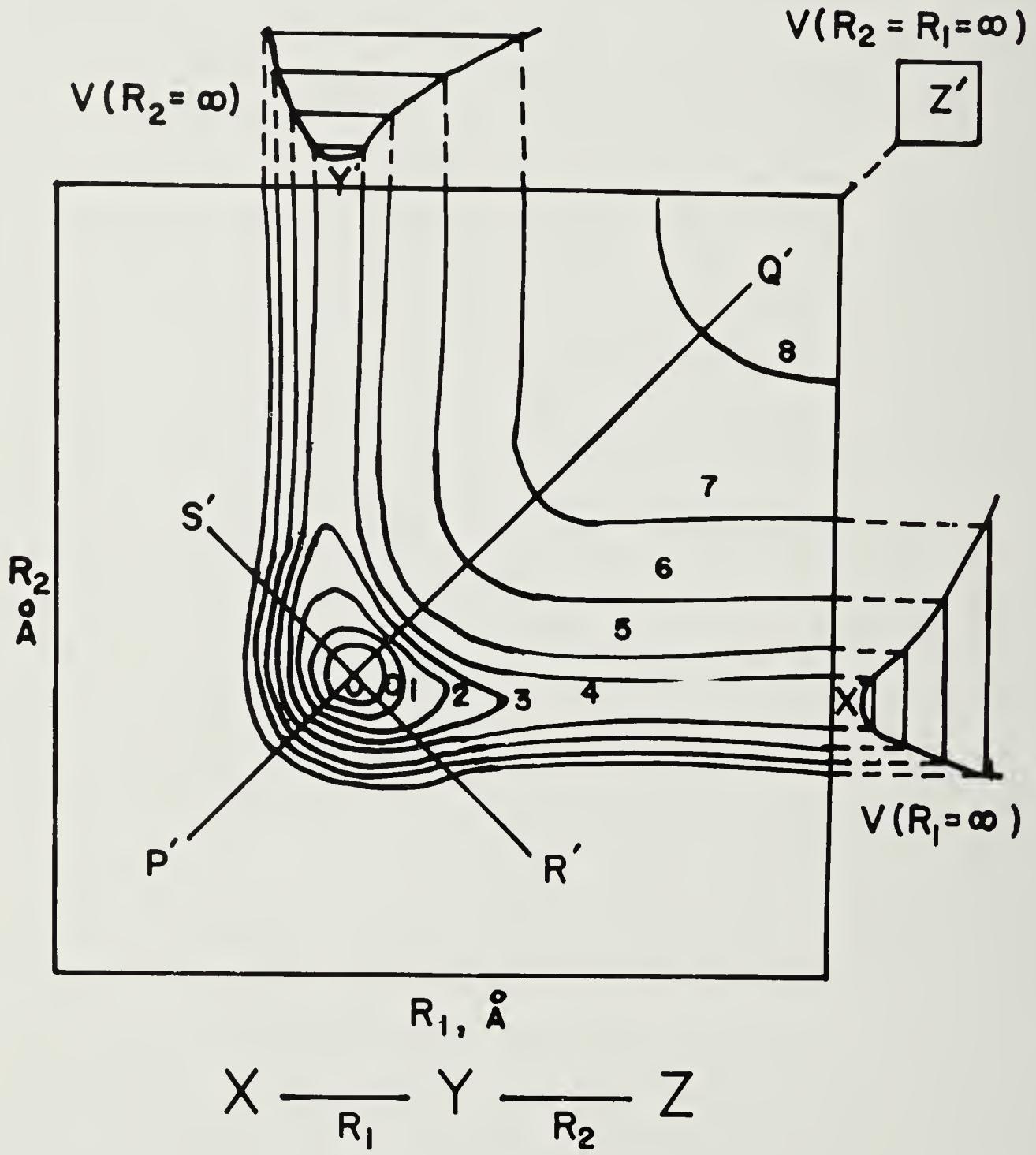

Fig. 1. Potential Energy Surface of a Linear Triatomic Molecule XYZ.

$= D_A [(1 + 3Z_A) \exp(-2a_A\rho_A) - 2(3 + Z_A) \exp(-a_A\rho_A)]/4$ (9)

Similar expressions can also be obtained easily for B, β and C, γ in both LEPS and MLEPS methods.

To calculate the classical energy of activation of a reaction, the above expressions are first used to obtain the potential energy surface for XYZ a collinear three atom system. Then the stretching and bending force constants are calculated from the potential energy surface. There are four extrema in the potential energy surface of a linear triatomic molecule XYZ (see Fig. 1) they are 0', X', Y', and Z'. A Taylor series expansion can be made in each extremum of the potential energy surface. Near Z' the linear, quadratic and also all the higher terms in the Taylor series expansion are zero. Near the region Y' and X' only the quadratic terms of the Taylor series exist, which are the Force constants of the diatomic molecule XY and YZ respectively.

About the region O' three quadratic terms exist, they are

$$f_{11} = \frac{\partial^2 V}{\partial R^2_1},\ f_{22} = \frac{\partial^2 V}{\partial R^2_2} \text{ and } f_{12} = \frac{\partial^2 V}{\partial R_1 \partial R_2} \quad (10$$

At a small departure from O', the potential energy can be discribed by the quadratic form,

$$V - V_O = (f_{11} r^2_1 + f_{22} r^2_2 + 2f_{12} r_1 r_2)/2 \quad (11)$$

where

$$r_1 = R_1 - R_{10},\ r_2 = R_2 - R_{20}$$

Therefore the force constant for a line through O, parallel to the R_1 axis is,

$$f_{11} = 2\Delta / r_1^2 \quad (12)$$

and that for the line through O, parallel to R_2 axis is,

$$f_{22} = 2\Delta V / r_2^2 \quad (13)$$

The force constant f_{12} is calculated through O, for the line COD or EOF neither parallel to R_1 nor R_2. The value of the interaction force constant f_{12} can then be found from the equation,

$$f_{12} = [f_C (1 + C^2) - f_{11} - C^2 f_{22}]$$

where,

$$f_C = f_{11} + C^2 f_{22} + 2C f_{12} \quad (14)$$

and

$$C = \frac{dR_2}{dR_1}$$

The potential energy function can be well expressed in terms of three co-ordinates R_1, R_2 and R_3. The bending angle Θ is related to the co-ordinates as

$$R^2_3 = R^2_1 + R^2_2 - 2R_2 R_2 \cos \Theta \quad (15)$$

The angular force constant $f\Theta$ is defiined by,

$$f = \frac{\partial^2 V}{\partial \Theta^2} = \frac{\partial}{\partial \Theta}\left(\frac{\partial V}{\partial \Theta}\right) = \frac{\partial}{\partial \Theta}\left(\frac{\partial V}{\partial R_3} \bullet \frac{\partial R_3}{\partial \Theta}\right) = \frac{\partial V}{\partial R_3}\left(\frac{\partial^2 R_3}{\partial \Theta^2}\right) + \left(\frac{\partial R_3}{\partial \Theta}\right)^2 \left(\frac{\partial^2 V}{\partial R^2_3}\right) \quad (16)$$

$$f = -\frac{R_1 R_2}{R_3}\left(\frac{\partial V}{\partial R_3}\right)_{R_1, R_2} \quad (17)$$

where the values of $\frac{\partial R_3}{\partial \Theta}$ and $\frac{\partial^2 R_3}{\partial \Theta^2}$ are obtained from equation (15).

The explicit equations for vibration frequencies of linear triatomic molecule are (Glasstone, et. al., 1941):

$\lambda_i = 1301.9\ \nu_i^{1/2}\ cm^{-1}$, where i = s, l, Θ and

$\nu s\ 1/2\ [L + (L^2 - 4M)^{1/2}]$

$$\nu_1 = \tfrac{1}{2}\,[L - (L^2 - 4M)^{\frac{1}{2}}]$$

$$\nu\Theta = f\Theta\,[\frac{1}{\frac{2}{R_1 M_X}} + \frac{1}{\frac{2}{R_2 M_Z}} + (\frac{1}{R_1} + \frac{1}{R_2})^2 \frac{1}{M_Y}]$$

$$L = \frac{f_{11}}{M_X} + \frac{f_{22}}{M_Z} + \frac{f_{11} + f_{22} + 2f_{12}}{M_Y}$$

$$M = \frac{(f_{11}f_{22} - f^2_{12})\,(M_X + M_Y + M_Z)}{M_X\,M_Y\,M_Z} \quad (18)$$

In the above equations, f is in units of 10^5dyne/cm, $f\Theta$ is in units of 10^{-11} ergs/radian^2, R is in Units of A°. M_X,M_Y and M_Z are the masses of atoms X, Y and Z respectively and are in gram-molar mass units. λ_S is the stretching frequency, $\lambda\Theta$ is the bending frequency and λ_1 is an imaginary number, included to consider the penetration of the energy barrier. After obtaining the classical energy of activation E_C, (see Table II) the activation energy of reaction E_O can be evaluated by the following equation

$$E_O = E_C + N\ (\Sigma\tfrac{1}{2}h\upsilon^{\ddagger} - \Sigma\tfrac{1}{2}h\upsilon_i) \quad (19)$$

where $\upsilon^{\ddagger}$ is the zero point frequency of the activated state. The zero point energy of the activated state, $E^{O}{}^{\ddagger}$ is

$$E^{O}{}^{\ddagger} = \tfrac{1}{2}\ (2\lambda\Theta + \lambda_S) \quad (20)$$

because $\lambda\Theta$ is doubly degenerate. Finally,

$$E_O = E_C + E^{O}{}^{\ddagger} - E^{O}{}_i \quad (21)$$

where $E^{O}{}_i$ is the zero point energy of the initial component or components. The present calculations have been carried out on an IBM 360-M40 computer and the results are shown in Table I-III.

TABLE 1. Constants used in Determining the Morse Equation

	^{r}eA (A)	D^{e} (Kcal/mole)	a	z
H_2	.74	109.4	1.94	.16
HF	.92	140.5	2.23	.16

TABLE 2. Calculated parameters for the activater.

	LEPS	MLEPS
R_1 (Å)	0.8565	0.7553
R_2 (Å)	1.3074	1.6036
f_{11} (mdyne/Å)	1.7648	5.0831
f_{22} (mdyne/Å)	-0.4559	-0.0798
f_{22} (mdyne/Å)	1.7017	0.3866
$f\Theta/R_1R_2$	0.0538	0.0149
E^{c} (Kcal/mole)	27.13	1.03

TABLE 3. Comparison of Energies of Activation Calculated by Different Methods.

	Present Calculation		LEP method (when coulombic binding energy is taken as 10 & 3.5 respectively	Wilkins' Calculation	Expt. Value
	LEPS method	MLEPS method			
$\lambda_s (cm^{-1})$	3439.3	4283.4			
$\lambda_\theta (cm^{-1})$	720.8	411.0			
$\lambda_1 (cm^{-1})$	989.11	307.6i			
E_0(kcal/mole)	27.91	2.13	5-15	1.6	1.7

DISCUSSION:

From Table III one can see that the activation energy of the $H_2 + F \rightarrow H + HF$ reaction obtained by MLEPS method is in much better agreement with the experimental result than by LEPS method. The MELPS method appears to provide a potential surface free of deep basins. However, the MELPS method still appears to be quite as empirical as the LEP method because the true square of the Heitler-London overlap intergral at the activated-state configuration is usually three times greater than the value required in the MLEPS method. Moreover, there can be no justification for using a constant square of the Heitler-London overlap integral for $H_2 + F$ (the value in fact changes with the change of H-H distance in the activated region). Nor can the use of the same square of the overlap integral value in different reactions be justified. Therefore, it is not unexpected that the MLEPS method is inferior to Wilkins' (1971) calculation of the activation energy for the $H_2 + F \rightarrow HF + H$ reaction. It seems that the MLEPS method may not be a good quantitative method but still is a useful qualitative method for calculating the activation energy of a reaction because it gives reasonable results and does not involve any complicated computations.

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IN VITRO OXYGEN UPTAKE BY TISSUES IN THE PRESENCE OF TRANQUILIZERS AND ANTIDEPRESSANTS

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ABSTRACT. The oxygen uptake by rat brain slices at 37° was evaluated by Warburg criteria before and after the introduction of various tranquilizers, antidepressants, phenobarbital and the antihistaminics, cyclizine and chlorcyclizine hydrochlorides, at levels of up to 100 μg and the differences analyzed for statistical significance. Reserpine chlorpromazine, prochlorperazine dimaleate, azacyclonol, benactyzine, hydroxyzine, chlordiazepoxide, diazepam, oxanamide, chlormezanone, chlorprothixene and doxepin and the antidepressants, imipramine, protriptyline and nialamide in addition to phenobarbital, depressed brain oxygen uptake. The *in vitro* respiration of brain and liver slices from rats injected s.c. 1 hr previously with several of the drugs, was in the range of the respective saline-injected controls.

Introduction

Few systematic studies are available on the action of tranquilizers and antidepressants on the *in vitro* oxygen uptake by brain and other tissues, except for the phenothiazines, notably chlorpromazine (CPZ). The latter has been investigated in regard to blood sugar (Gupta *et al.*, 1960; Jori *et al.*, 1964; Susten *et al.*, 1971) and has been shown to inhibit cytochrome oxidase and adenosine triphosphatase (Abood, 1955; Bernsohn *et al.*, 1956; Dawkins *et al.*, 1959, 1960; Williams *et al.*, 1963), succinoxidase (Helper *et al.*, 1958), alcohol dehydrogenase (Wollemann and Keleti, 1962; Khouw *et al.*, 1963), brain phosphorylase (Iriye and Simmonds, 1967), brain cyclic 3'5'-adenosine monophosphate (Uzinov and Weiss, 1971) and liver mitochondrial NADH-cytochrome c reductase (Dawkins *et al.*, 1959), among others. Sodium and potassium-activated adenosine triphosphatase of beef brain was also depressed by hydroxyzine, haloperidol and diazepam (Ueda *et al.*, 1971). An uncoupling of oxidative phosphorylation of brain was viewed as a prominent feature in the pharmacological action of CPZ (Abood, 1955; Bernsohn *et al.*, 1956) and an inhibition of oxidative phosphorylation also occurred with liver mitochondria (Gallagher *et al.*, 1965).

With respect to the oxygen uptake by animal brain, low to moderate levels of CPZ proved inhibitory (Courvoisier *et al.*, 1953; Peruzzo and Forni, 1953; Finkelstein *et al.*, 1954; Kok, 1956; Lindan *et al.*, 1957a,b; McIlwain and Greengard, 1957; Kozák *et al.*, 1958; Yanagawa, 1958) as was likewise the case with imipramine (Abadom *et al.*, 1961). According to Bernsohn *et al.* (1956), the aerobic respiration of brain was inhibited while the anaerobic metabolism was insensitive to CPZ. The latter was without effect on the respiration of such tissues as liver (Peruzzo and Forni, 1953; Grenell *et al.*, 1955). The distribution and concentration of several tranquilizers in the brain have been investigated. Thus, CPZ was found to inhibit the metabolism of the hypothalamus and the posterior lobe of the pituitary gland (Wase *et al.*, 1956; Larsson, 1961) and the accumulation of phenothiazines in rat brain following their injection has been reported by Mahju and Maickel (1969). Amitriptyline readily enters the brain (Hucker and Porter, 1961) and its distribution has been demonstrated in rabbit and cat brain (Corona *et*

al., 1971; Cassano *et al.,* 1965a,b). Reports are also available on the concentration of diazepam in the newborn monkey brain (van der Klijn and Wijffels, 1971 and the uptake of imipramine by rat brain (Schneider and Schneider, 1969).

In the present study, a number of tranquilizers and antidepressants were investigated in relation to their action on the oxygen uptake by rat brain slices. The experiments were so implemented as to afford relatively similar conditions for the comparison of the effects of the agents. For additional correlations, phenobarbital and the antihistaminics, cyclizine and chlorcyclizine hydrochlorides were included. In yet another series, high levels of several of the agents were injected s.c. into rats and the oxygen uptakes by liver and brain slices compared with those of the respective controls.

MATERIALS AND METHODS

The drugs were bulk powders of USP or good grade and unless otherwise stated, where salts were employed, these comprised the hydrochlorides. The dosages are based on the latter. The agents and sources were as follows: captodramine (Ayerst); phenyltoloxamine citrate (Bristol); cyclizine and chlorcyclizine (Burroughs Wellcome); lyophilized Ritalin® hydrochloride or methylphenidate (Ciba); imipramine (Geigy); amitriptyline, chlorprothixene, chlordiazepoxide and diazepam (Hoffman-La Roche); phenaglycodol (Lilly); benactyzine, emylcamate and protriptyline (Merck Sharpe & Dohme); azacyclonol, oxanamide and pipradrol (Merrell); reserpine (Nutritional Biochemicals); doxepin, hydroxyzine and nialamide (Pfizer); CPZ, prochlorperazine dimaleate and tranylcypromine sulfate (Smith Kline & French); mephenesin carbamate (Squibb); chlormezanone (Sterling-Winthrop); ectylurea (Upjohn); meprobamate (Wallace) and promazine (Wyeth). In a few experiments, parenteral Valium® (Roche) and Serpasil® (Ciba) were used. Male Charles River rats of 250-300 g in weight comprised the experimental animals throughout. They were administered Teklad rat feed and water *ad lib.*

Each animal was sacrificed by swift decapitation, the brain removed and the cortex sliced in its entirety, the slices from 2-3 rats being pooled in chilled saline for each Warburg run. Portions of the randomized slices were gently blotted, weighed and transferred to the main chamber of the flask together with 1.8 ml of Locke-Ringer solution. The test drug as a solution or a very fine suspension in the same medium was introduced at a volume of 1.0 ml into the sidearm; 0.20 ml of 20% potassium hydroxide and fluted filter paper were inserted into the center well. A total of 2-4 drugs was investigated per run which involved 17 flasks in addition to the thermobarometer. The system was gassed with 100% oxygen and readings taken over an interval of 20 min following equilibration at 37°. The test solution was then tipped into the main chamber and after 10 min, readings were again recorded over a period of 20 min. The differences in oxygen uptake were determined and the significance tested by calculation of the Fisher *t*-values. The above procedures have been discussed previously in greater detail (Spencer *et al.,* 1964; Umbreit *et al.,* 1964).

With the injection series, the drug solution or saline was administered s.c. and the animals sacrificed 1 hr later. Brain as well as liver were sliced and processed as in the above except that 2.8 ml of Krebs-Ringer-phosphate solution comprised the medium and readings were taken over a period of 30 min; no fluid was used in the sidearm.

RESULTS AND DISCUSSION

The differences in Qo_2 or $\mu l\ O_2$/mg dry tissue/hr, before and after introduction of the drugs together with the respective standard errors (SE) and Fisher *t*-values are presented in Table 1. The agents were screened at 1.0, 10 and 100 μg, the 10 μg-level being the more prominent one. Of the major tranquilizers, reserpine as a fine suspension at 1.0 μg/ml depressed the oxygen uptake of rat brain slices as was also the case with the parenteral product and with the two phenothiazines, the well-known depressant, CPZ and prochlorperazine; the difference with promazine was not significant. The triphenylmethane tranquilizers, azacyclonol, benactyzine and hydroxyzine, markedly suppressed brain oxygen uptake at 10 μg but captodramine, even at 100 μg, proved ineffective. Both diazepines diminished the oxygen consumption but the propanediol derivatives, mephenesin carbamate, meprobamate and phenaglycodol were without action at the levels screened. In the miscellaneous group of tranquilizers, ectylurea and emylcamate comprised inactive members, whereas chlormezanone, doxepin and chlorprothixene inhibited brain respiration. In this respect, the latter phenothiazine analog simulates the activity of CPZ.

Of the seven antidepressants listed in Table 1, the hydrazide, nialamide, depressed brain oxygen uptake in addition to the N-heterocyclic compound based on phenothiazine, imipramine. The latter finding is in agreement with prior studies (Abadom *et al.*, 1961). On the other hand, the homocyclic derivative, amitriptyline, was without effect at a comparable level but the closely allied protriptyline, caused an inhibition and at the 5% level of probability. In line with earlier reports, phenobarbital depressed the oxygen uptake when introduced at a level of 10 μg. Cyclizine and chlorcyclizine which were included with the idea of correlating greater inhibitory activity with the presence of the nuclear chloro-group as noted for the pair, promazine and CPZ, were without effect on the differences. In fact, possibly a change in the direction of a stimulation might be construed for cyclizine.

Oxygen uptake findings for brain and liver slices from 12 controls and groups of 10 rats each injected s.c. with very high dosages of meprobamate, Serpasil®, CPZ, Valium®, methylphenidate and hydroxyzine and sacrificed 1 hr later appear in Table 2. One value was obtained per tissue pool from each rat. Without exception, the mean values of the drug-treated rats were in the range of the respective controls. Presumably, the cellular changes or the extent of deposition of the drugs in the organs are not too great under these conditions. The negative findings with liver are also apparent from earlier studies (Peruzzo and Forni, 1953; Wase *et al.*, 1956). In this conjunction, Gey *et al.* (1965) reported that rats injected i.p. with a single dosage of CPZ, phenobarbital or reserpine underwent a depression in both glucose-6-phosphate and fructose-6-phosphate and in line with earlier accounts, brain glycogen accumulated in the presence of phenobarbital and reserpine but not with CPZ. A similar effect had been noted with a single injection of CPZ by others (Máthé *et al.*, 1961) but on repeated administration over protracted periods of time, the glycogen level rose.

Differences among a few of the psychotropic drugs are also evident from other types of *in vitro* metabolic studies. Saha and Ghosh (1972) reported an inhibition of glucose oxidation by yeast cells with several phenothiazine tranquilizers in addition to phenothiazine dima-

TABLE 1. Differences in Oxygen Uptake of Brain Slices in the Presence of Drugs[a]

Drug	Level 100 μg	10 μg	1.0 μg
Tranquilizers			
Rauwolfia Drugs			
Reserpine[b]		1.03 ± 0.26 (22)**	1.18 ± 0.18 (18)**
Serpasil®		1.25 ± 0.13 (18)**	
Phenothiazines			
CPZ		0.62 ± 0.06 (15)**	
Prochlorperazine dimaleate		1.49 ± 0.20 (18)**	
Promazine		0.63 ± 0.39 (17)	
Diphenylmethane Derivatives			
Azacyclonol[b]		1.73 ± 0.15 (21)**	
Benactyzine	3.10 ± 0.52 (17)**	1.25 ± 0.17 (12)**	
Hydroxyzine	1.81 ± 0.44 (15)**	1.05 ± 0.34 (15)**	
Captodramine	—0.17 ± 0.39 (16)	0.28 ± 0.31 (16)	
Propanediol Derivatives			
Mephenesin carbamate		0.28 ± 0.29 (22)	
Meprobamate	—0.63 ± 0.24 (18)	0.32 ± 0.31 (16)	
Phenaglycodol[b]			0.32 ± 0.49 (19)
Benzodiazepines			
Chlordiazepoxide		1.19 ± 0.40 (17)*	
Diazepam		0.84 ± 0.02 (15)**	
Miscellaneous			
Ectylurea	0.26 ± 0.23 (14)	—0.13 ± 0.41 (12)	
Oxanamide		0.54 ± 0.20 (19)*	
Emylcamate	—0.43 ± 0.27 (15)	0.11 ± 0.11 (13)	
Chlormezanone		1.01 ± 0.26 (20)**	
Chlorprothixene[b]			1.07 ± 0.06 (11)**
Doxepin		0.77 ± 0.27 (19)*	
Antidepressants			
Imipramine		1.14 ± 0.35 (19)**	
Protriptyline		0.57 ± 0.22 (19)*	
Amitriptyline		0.71 ± 0.36 (18)	
Pipradrol		0.24 ± 0.22 (19)	
Methylphenidate	—0.20 ± 0.34 (14)	0.32 ± 0.33 (17)	
Nialamide		1.05 ± 0.20 (14)**	
Tranylcypromine sulfate		0.46 ± .0.56 (13)	
Phenobarbital		0.58 ± 0.21 (18)*	
Cyclizine	—1.09 ± 0.54 (13)	—0.32 ± 0.50 (14)	
Chlorcyclizine	0.72 ± 0.72 (15)	0.57 ± 0.51 (21)	

[a] All values are Q_{O_2} differences (± SE), a positive one denoting a depression in respiration. A figure in parentheses refers to the number of flasks employed. The weight of tissue per vessel ranged up to 100 mg.

[b] Due to the low solubility of the drug, a fine suspension in saline was used.

*$P < 0.05$.

** $P < 0.01$.

TABLE 2. Respiration of Brain and Liver Slices from Rats Injected S.C. with Various Drugs and Sacrificed 1 Hr. Later

Drug	Number of rats	Dosage, mg/kg	Brain $Q_{O_2} \pm SE$	t	Liver $Q_{O_2} \pm SE$	t
Control (saline)	12		7.44 ± 0.19		4.48 ± 0.25	
Meprobamate	10	128	7.40 ± 0.34	0.62	4.43 ± 0.32	0.12
Serpasil®	10	4.00	7.99 ± 0.33	1.53	4.44 ± 0.29	0.10
CPZ	10	30.0	8.10 ± 0.30	2.00	4.55 ± 0.16	0.23
Valium®	10	10.0	7.10 ± 0.55	0.46	4.85 ± 0.13	1.19
Methylphenidate	10	20.0	7.19 ± 0.34	0.68	4.61 ± 0.26	0.35
Hydroxyzine	10	48.0	7.26 ± 0.27	0.56	5.06 ± 0.13	1.93

leate, reserpine and mephenesin, the activity being less with the last three agents. Of a group of drugs screened on the succinoxidase system, the phenothiazines displayed the strongest depressive activity, followed by reserpine and oxanamide was relatively inactive (Helper *et al.*, 1958). Brain succinoxidase was less sensitive than the liver system and the action of the agents was thought to be unrelated to the mechanism of tranquilizing action. In yet another investigation (Gershbein, 1966), CPZ in amounts of up to 0.50 mg, did not affect the oxygen uptake by the isolated rat diaphragm although both the glucose utilization and glycogen content were depressed. The phenothiazine, promazine, inhibited only the glucose uptake; barbituric acid, meprobamate and reserpine were without effect on any of these parameters. Accordingly, the above data do not parallel the current brain oxygen uptake findings but rather complement or amplify many of the physiological characteristics of these diversified psychotropic agents.

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PYOCIN TYPING: A METHOD OF CATEGORIZING *PSEUDOMONAS AERUGINOSA* CULTURES

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ABSTRACT: A set of pyocin typing—indicator strains of *Pseudomonas aeruginosa* were identified and used to type 200 cultures of this organism that were isolated from a variety of sources. These results were compared with similar data derived with a set of indicator strains previously used by other investigators. This method of bacteriocin typing is outlined and discussed.

Due to the seriousness of antibiotic-resistant *Pseudomonas aeruginosa* infections and the strong indication that man and domestical animals are the natural reservoirs of this organism (Hoadley et al., 1968; Gorgan, 1966), epidemiological methods are needed, particularly in hospital environments. In addition, investigators, who isolate these organisms from soil, water and other natural sources, also desire a means of categorizing their isolates with a simple, rapid method. Phage typing and serological methods have been used, but these are often costly, variable and time consuming. Holloway (1960) suggested that the bacteriocins produced by *P. aeruginosa* (pyocins) might be used in a typing scheme. Darrell and Wahba (1964), Gillies and Govan (1966), Osman (1965) and Zabransky and Day (1969) have worked with such systems and found approximately 90% of the cultures examined produced pyocins against their indicator strains.

We, too, examined this type of system by isolating a set of indicator strains and then compared the results of this set with the results of the set used by Darrell and Wahba (1964).

Materials and Methods

The organisms used in this study were isolated from various pathological and non-pathological sources including: human and animal infections, human fecal material, veterinary autopsy specimens, contaminated tissue culture, soil, water, sewage, food stuffs, grain and plankton.

All the organisms were examined for: growth on 1% (w/w) triphenyltetrazolium chloride in nutrient agar (Wahba and Darrell, 1965); liquefication of gelatin; pyocyanin production; growth at 41C utilization of glycine and hexadecane as a sole carbon source; the inability to use m-inositol, trehalose and mannose as sole carbon sources (Stanier et al., 1966). The results of these tests and the preliminary screening tests of motility, the gram stain, the oxidase reactron, oxidation of glucose in Hugh and Leifsons medium (1953), and colonial characteristics were used to distinguish *P. aeruginosa* from *P. fluorescens* and *P. putida.*

The pyocin indicator strains used by Darrell and Wahba (1964) and their most recent typing scheme were obtained from Dr. M. T. Parker, Central Public Health Laboratory, Colindale Avenue, London England.

All other cultures were Kansas State University stock cultures. Cultures were maintained on duplicate, refrigerated nutrient agar slants and transferred monthly.

PYOCIN TYPING

The method of pyocin typing was similar to those described by Wahba (1963) and Gillies and Govan (1966). Nutrient agar (Fishers) supplemented with 0.1% (w/w) sodium citrate, 0.1% (w/v) dipotassium hydrogen phosphate and 0.001% (w/v) $FeCl_3.6H_2O$ was the medium used for pyocin typing. The ferric chloride was added to allow uniform growth with all strains since added iron inhibits the iridescent phenomenon often associated with *P. aeruginosa* (Wensinck et al., 1967).

The typing procedure was as follows:

1. A heavy streak, 2 cm wide of the organism to be examined was smeared on the agar surface with a sterile cotton tipped applicator and incubated at 30C for 16 hr. Glass petri dishes, 15 cm dia were used.
2. The dishes were then inverted, filter paper soaked in chloroform was placed in the lids of the dishes and the chloroform vapors were exposed to the growth for 15 min.
3. A clean glass microscope slide was used to remove the growth from the surface of the agar and then the agar surface was again exposed to chloroform for another 15 min.
4. The filter paper was removed from the lids of the dishes and the agar surface was exposed to the air for 5 min. Then the plates were covered and allowed to remain at room temperature for 1 hr.
5. Cross streaks of the indicator strains were made perpendicular to the area of the original growth and incubated 12 to 14 hr at 30C. Indicator strains were grown prior to inoculation in nutrient broth to approximately 10^8 cells per ml.
6. Three consistent typings were required before a type was assigned to a particular culture.

Demonstration of a Plaque Forming Agent

A culture of the organism to be tested was grown in nutrient broth for 18 hrs at 30C on a rotary shaker. The culture was centrifuged, filtered through a 0.46 μ membrane filter, a few drops of chloroform were added to the supernatant and then the supernatant was diluted and spotted on a nutrient agar plate smeared with the indicator strain. After overnight incubation at 30C, the clear areas were picked and added to 0.5 ml nutrient broth with a drop of chloroform. This suspension was diluted and spotted on lawns of the indicator strain. If the agent was transferable three times and formed discrete plaques it was considered to be a bacteriophage.

Demonstration of an Inhibitory Agent Permeable to Dialysis Tubing:

Sterile membrane filters (0.46 μ) and pieces of dialysis tubing were aseptically layered on nutrient agar plates. A wide streak of the test organism was smeared on the filter or dialysis tubing and incubated 18 hr. at 30C. After incubation the tubing or filter with the growth was pealed off the agar and the pyocin typing procedure was followed.

RESULTS

The incubation time and temperature of the initial inoculum was determined by trial and error to be optimal for typing at 30C and 16 hr. Longer incubation times or higher temperatures apparently inactivated or destroyed pyocins.

Eight indicator strains were selected from over 200 isolates by

means of pyocin typing the isolates against one another and then those with varied patterns were chosen as the indicator strains. Table 1 lists the indicator strains selected for this study. With these strains, 15 pyocin patterns were obtained from the 200 isolates (Table 2). Seven isolates did not produce any reaction to our indicator strains.

When the same 200 cultures were examined using the Darrell and Wahba indicator strains, the major types listed by Darrell and Wahba were present, but also many other patterns. Only 4 cultures could not be typed. The same 4 could not be typed with our indicators. Zabransky and Day (1969) also noted several other patterns and tried to resolve this problem by denoting them as subtypes. Even with these subtypes, some cultures did not fit this typing scheme. Instead of attempting to use a typing scheme, the organisms were noted by the indicator

TABLE 1. "K" Pyocin Indicator Strains.

STRAIN	SOURCE
K4	soil-dodecane enrichment
K5	tissue culture contaminant
K9	porcine autopsy material
K11	bovine brain
K12	chicken meat
K15	porcine autopsy material
K17	milk
K19	equine autopsy material

TABLE 2. Pyocin Patterns of *Pseudomonas aeruginosa* Isolates With "K" Indicator Strains.

Pattern of Strains Inhibited	Number of Isolates With Pattern
K4	14
K12	18
K4, K12	1
K4, K12, K15	7
K4, K11, K15	22
K4, K11, K19	1
K11, K12, K15	1
K4, K11, K12, K19	43
K4, K12, K15, K17	1
K4, K5, K12, K15	3
K4, K11, K12, K15, K19	59
K4, K9, K11, K12, K19	2
K4, K11, K12, K15, K17, K19	14
K4, K5, K11, K12, K15, K19	1
K4, K5, K9, K11, K12, K15, K19	27
none	7
	200

strains they inhibited, a method generally used in phage typing schemes.

There was a correlation between some of our pyocin indicator strains and the Darrell and Wahba set. Strain K4 of our set corresponded to 8/39; K12 corresponded to 577 and K15 corresponded to B10, although a few exceptions did occur. This correlation was only the relationship of a similar inhibition pattern. Pyocyanin production, the formation of the iridescent material and colonial characteristics of these strains were not similar.

Twenty strains were pyocin typed every six months during a two year period and no variations were noted in the pyocin patterns of these strains.

The inhibition zones produced during pyocin typing were examined in detail and often found to contain a transferable lytic agent. Pyocins, by definition fade on dilution instead of forming discrete plaques and are unable to multiply within cells. However, agents were isolated which formed plaques and were transferable. For example, K19 produced pyocins against strains M8 and B26 but carried a phage for strains 577 and K12.

Staphylococcus aureus, Micrococcus lysodeikticus, Serratia marcescens, Bacillus subtilis, Alkaligenes viscolatis, Escherichia coli 3968 and 3969 (colicin producers), *Chromobacterium* sp. and three cultures of *P. fluorescens,* did not inhibit either set of indicator strains and therefore were considered unable to produce phage or bacteriocins against *P. aeruginosa.*

When these organisms were used as indicator strains, they were often inhibited by *P. aeruginosa* (Table 3). This was true only if the *P.* aeruginosa was a pyocyanin producing culture. With dialysis tubing and membrane filters, the agent inhibiting organisms other than *P. aeruginosa* was shown to pass through both dialysis tubing and membrane filters, whereas, pyocins and phage could only permeate the membrane filter.

TABLE 3. Growth Inhibition by *Pseudomonas aeruginosa* towards Unrelated Organisms.

Organism tested	*P. aeruginosa* strains					pyocyanin** only
	K11*	K17	K5*	K12*	K14*	
Staphylococcus aureus	+	—	+	+	+	+
Micrococcus lysodeikticus	+	—	+	+	+	+
Serratia marcescens	—	—	—	—	—	—
Bacillus subtillis	+	—	+	+	+	+
Alkaligenes viscolatis	+	—	+	+	+	+
Chromobacterium sp.	—	—	+	—	+	+
Escherichia coli	+	—	+	+	+	+

* pyocyanin producing strains
** pyocyanin 30 ug/ml in nutrient broth
\+ refers to growth inhibiton
— refers to no change

DISCUSSION

Pyocin typing was clearly applicable to our purpose of distinquishing between isolates of *P. aeruginosa.* During these investigations this technique was also used: to show that the organisms were capable of bacteriocin production as a diagnostic method for the identification of *P. aeruginosa* (Wahba and Darrell, 1965); as a method to determine if two isolates from the same specimen were different; and to determine if a stock culture was contaminated or formed dissociates if there was a visible change in culture characteristics.

Since agar that had supported the growth of the culture was also used for indicator strains, the metabolic products produced by the original culture must be taken into account in the technique pyocin typing.

This study has shown the pyocin typing often involved agents in the agar other than bacteriocins and were probably bacteriophages. Pigments of *P. aeruginosa* were apparently not toxic to *P. aeruginosa.* The term pyocin typing has been widely accepted, however, this investigation indicated that one should be aware of agents other than bacteriocins causing growth inhibition.

This technique, itself, was inexpensive and required little work time, but the results were not available until two days after the procedure was begun. Reliability was attested to by the fact that 20 strains retained the same pyocin types for two years and there was very little variability in the other cultures. Shionoya and Homma (1968) reported that dissociated strains often showed different susceptibilities than the parent strain to pyocins. The indicator strains used in our study did not form notable dissociates during the period of this investigation. Use of organisms other than *P. aeruginosa* as indicator showed the need that indicator strains must be *P. aeruginosa* otherwise false results would be likely. Organisms other than *P. aeruginosa* did not produce agents that inhibited the growth of *P. aeruginosa.* Only a few known cultures were reported in this study, however, many organisms other than *P. aeruginosa* were encountered during the progress of this work.

The use of the Darrell and Wahba indicator strains as a control were important because this set has frequently been used by other investigators and therefore should serve as a standard until more defined standards are formed. The time and temperature of pyocin typing has been disputed by most investigators in this field. Time and temperatures longer than those used in this study apparently cause inactivation of some pyocins and therefore the lower temperature was used to give the maximum inhibition. Gillies and Govan (1966) recommended the use of a lower growth temperature however, Wahba (1963) and Zabransky and Day (1969) used 37C temperature. With such discrepancies in technique, standaridized procedures are not likely to be obtained.

Bacteriocin producting by organisms other than *P. aeruginosa* has been noted in the literature (Reeves, 1965) and used in the classification of these organisms (Farmer, 1972; Slopek and Maresz-Babczyszin, 1967). Therefore this technique can be easily and cheaply applied for classifying bacteriocin-producing organisms obtained in survey studies.

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THE IRIDESCENT MATERIAL AND PYOCYANIN OF PSEUDOMONAS AERUGINOSA

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ABSTRACT.—Strains of *Pseudomonas aeruginosa* producing an entire film of iridescent material over the colony did not produce pyocyanin on nutrient agar or on 2 per cent glycerol-nutrient agar unless additional iron was incorporated into the medium. Iridescent material was produced on 51 of the 205 strains isolated in this study and 3 strains that produced the iridescent material were unable to form pyocyanin. There was no apparent relationship between pyocin types and the production of pyocyanin or the iridescent material.The majority of cells in iridescent colonies were viable. The strains used in this study were not "cured" of pyocin types or the iridescent phenomenon by the methods used to cure other organisms of episomal elements. Non-iridescent cultures were isolated from iridescent strains when grown on demethylchloretetracycline-nutrient agar. These organisms retained the same pyocin types as the parent strain. Single carbon source studies indicated that the most likely precursor to the iridescent material was anthranilate.

Since its discovery, the iridescent phenomenon has been considered to be caused by a lytic event. Hadley (1924) showed that an organism capable of producing the iridescent material carried a phage for non-iridescent strains, but the iridescent material was not produced in the plaques on the non-iridescent strains. More recent studies (Warner, 1950; Don and Van Den Ende, 1950; Sierra and Zagt, 1960; Berk, 1963, 1966; Wensinck et al., 1967 and Zierdt, 1971) indicated that there was little evidence in favor of phage mediated lysis. Berk (1963) refered to the iridescent material as "unlysable remnants of the lysed cells:, however, Wensinck et al. (1967) identified this material as a 2-alkyl-4-quinolinol. The production of these substances by *P. aeruginosa* has been reported since 1952 (Wells, 1952) but it was not until the work of Wensinck et al., (1967) that this material was related to the iridescent phenomenon.

Warner (1950) noted the iridescent material was generally associated with those cultures that produced pyocyanin in abundance. This relationship, however, was not expounded. Both pigmentation and iridescence were stimulated by glycerol (MacDonald, 1963; Wensinck et al., 1967), while addition of iron (Wensinck et al., 1967) inhibited the formation of the iridescent material. Hellinger (1951), using only one strain of *P. aeruginosa,* concluded that iron was not essential for the production of pyocyanin, whereas Burton et al. (1948) reported iron essential for pyocyanin production. The requirement of iron for pyocyanin production may be a moot point, but it bears consideration since the pigment has value as a diagnostic tool and its function remains unknown. We noted an obvious relationship between pyocyanin formation and the iridescent phenomenon while examining the different colonial forms of *P. aeruginosa* on media with and without added iron. This paper also reports on viability on the iridescent colonies.

Materials and Methods

Organisms. Two hundred and five strains of *P. aeruginosa* were isolated from a variety of sources includ-

ing soil, water, and human and animal pathological specimens. The organisms were identified as *P. aeruginosa* by the methods described by Wahba and Darrell (1965). All strains were pyocin typed with the strains used by Darrell and Wahba (1964) following the methods of Gillies and Govan (1966). Pyocin tests strains were obtained from Dr. M. T. Parker of the Central Public Health Laboratory, London, England.

Media. Gessard's medium was used for the production of pyocyanin in liquid culture since it has shown to stimulate pigment production (Burton et al., 1948). This medium consisted of: 5 percent glycerol, 2 percent peptone, 2 percent $MgSO_4 \cdot 7H_2O$, 0.04 percent K_2HPO_4 in distilled water. Ferric sulfate was added at a concentration of 0.001 percent wherever "iron" was used. Nutrient agar (Biocert, Fisher Scientific Company, Fairlawn, New Jersey), and 2 percent (w/v) glycerol-nutrient agar were prepared as directed by the manufacturer. A mineral salts agar base (Burns and Harris, 1953) with 0.2% (w/v) of either glucose glycerol, glycine, alanine, trypotophan, sodium acetate, sodium pyruvate, asparagine, sodium glutamate, sodium malate, sodium citrate or sodium anthranilate as sole carbon source was used for the determination of the nutritional requirements for the iridescent material. All glassware was washed with acid and rinsed with distilled water.

Curing. Methods described to "cure" bacteria other than *P. aeruginosa* of episomal elements were used in attempts to alter either the pyocin type or the iridescent phenomenon. These methods included cobalt chloride (Hirota, 1957) and acridine orange (Hirota, 1960) as used on *Escherichia coli:* the acridine orange treatment as used on *Proteus morganii* (Smit et al., (1968) and the mitomycin acridine treatment as used on *Bacillus subtilis* (*Seaman* et al., 1964).

Viable Cell counts. Equal size colonies of a strain growing on nutrient agar and on nutrient agar supplemented with 0.001% $FeCl_3 \cdot 6H_20$ were aseptically cut from the agar and shaken in 100 ml of nutrient broth and plated on nutrient agar.

Culture Viability. Each of ten nutrient agar slants in screw cap tubes were inoculated with 0.1 ml of a 10^8 cell/ml suspension of bacteria. The cultures were then incubated continuously at 30C and every five days, one slant was removed from the incubator and streaked for viability on nutrient agar.

Pyocyanin Assay. Cells were inoculated in 10 ml of Gessard's medium in a 50 ml Erlenmeyer flask and were incubated with and without shaking for 3 days at 30C or 1 day at 37C as noted. The suspensions were acidified with dilute acid and centrifuged. The clarified supernatant was neutralized with dilute NaOH, extracted with chloroform and read at 685 nm in a Spectronic 20 spectrophotometer.

RESULTS

While examining many isolates it was noted that strains showed different types of iridescent phenomena. Some strains formed colonies with central pits that contained the iridescent material (Fig. 1). In general the iridescent material was confined to these pits and did not spread over the colony. These strains produced pyocyanin on nutrient agar without added iron. Other strains produced a continuous film of iridescent material which covered the entire colony (Fig. 2). This group

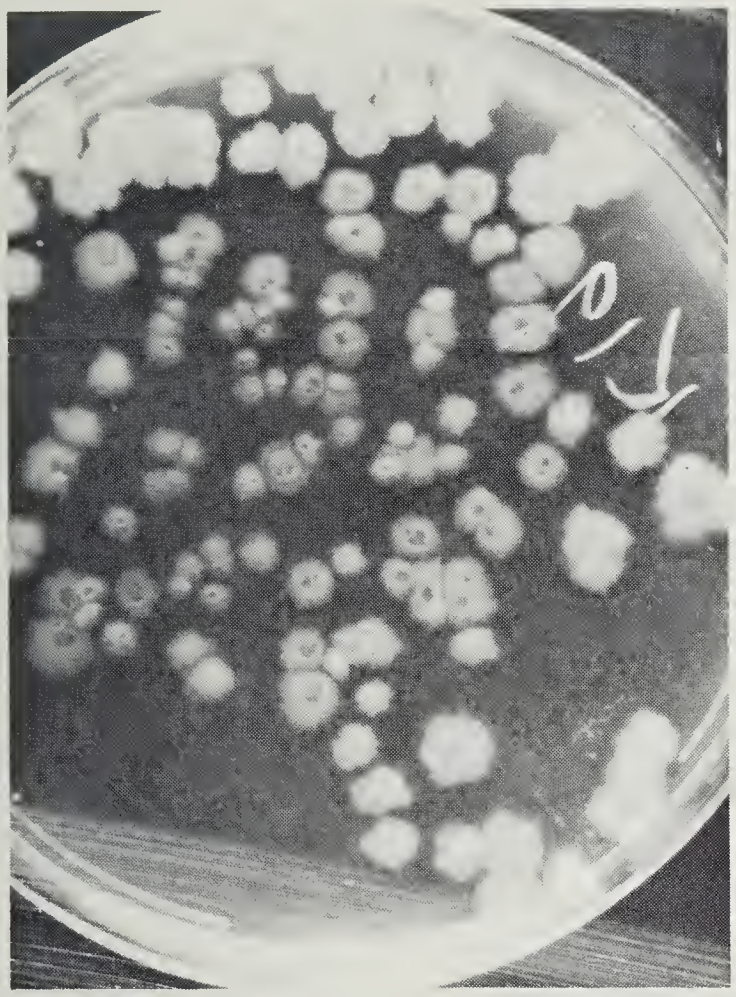

FIGURE 1. Iridescent material in pits of colonies of *Pseudomonas aeruginosa*. K19G.

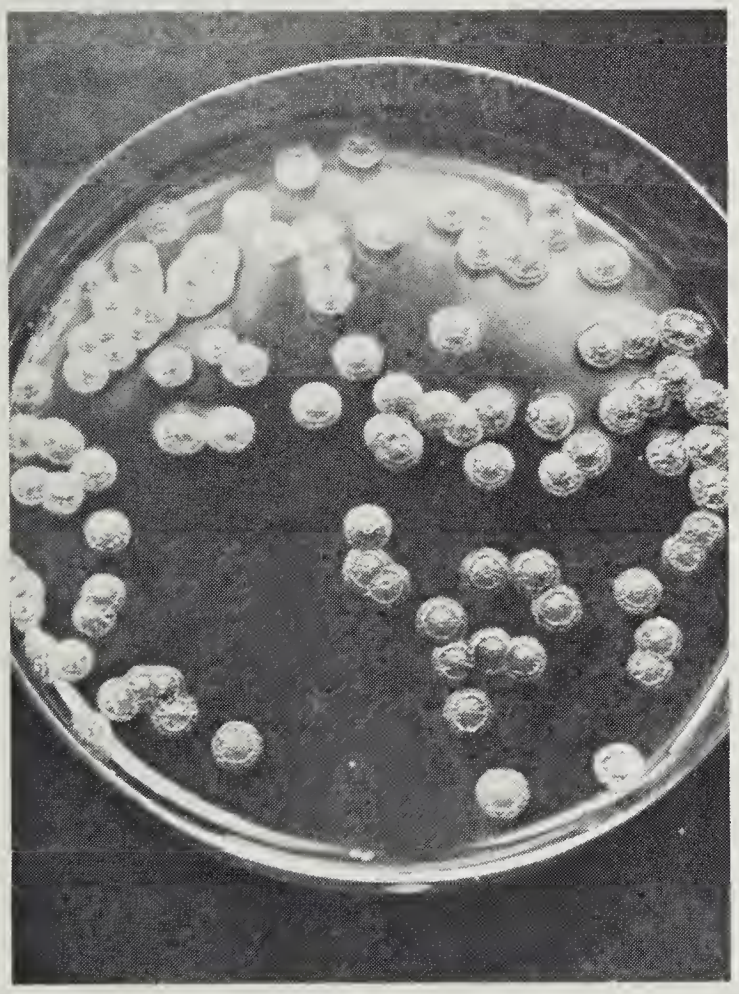

FIGURE 2. Iridescent material completely covering colonies of *Pseudomonas aeruginosa*. K12G.

did not produce pyocyanin on nutrient agar or on 2 percent glycerol-nutrient agar but did form the pigment if iron was incorporated into these media. There were three strains that produced the iridescent material but did not produce pyocyanin on any of the media used even when the production of the iridescent material was suppressed. Other strains required the presence of glycerol to stimulate iridescence and some strains did not produce iridescence under the conditions employed in this study. The iridescent material was produced by 51 of the 205 strains isolated in this study.

The requirement of iron for the production of pyocyanin by the iridescent strains of *P. aeruginosa* was verified in Gessard's liquid culture medium (Table 1). Ferric nitrate, ferric chloride of ferrous chloride could be substituted in these studies. Table 2 shows the relationship between the iridescent material and pyocyanin of 25 selected cultures.

The pyocin types of these organisms were not affected by the incorporation of iron in the culture medium and the types could not be correlated with the formation of pyocyanin or the iridescent material (Table 3).

Purified iridescent material from two strains grown on nutrient agar or on acetate-mineral salts agar had similar ultraviolet spectra identical to the spectrum reported by Wensinck et al. (1967) for the 2-alkyl-4-quinolinol compounds.

Viable Cell Counts. The number of viable cells in colonies expressing the iridescent phenomenon and in colonies of the same strain grown on a medium that inhibited the iridescent material were examined (Table 4). Two strains were used for comparisons in these experiments. Colonies of strain K12G were completely covered with the iridescent material

TABLE 1. Production of Pyocyanin in Gessard's Medium.

Strain	O. D. 685 mμ[2]	
Stationary cultures[1]	With iron	Without iron
K12G	> 2.0	0.2
K19G	> 2.0	0.5
Shaken cultures[1]		
K12G	0.01	0.04
K19G	0.04	0.05

1. Cells were inoculated in 10 ml of Gessard's medium in 50 ml Erlenmeyer flasks and incubated 3 days at 30C.
2. Optical density of supernatant fluid read at 685 mμ in a Spectronic 20 spectrophotometer.

TABLE 2. Production of Pyocyanin and Iridescent Material by *Pseudomonas aeruginosa*

Culture	*Pyocyanin*[1]	*Iridescent*[2]	*OD*[3] *685nm*
G-1	+	—	.15
G-2	+	—	.03
G-3	+	—	.15
G-4	+++	+	.38
G-5	+	+	.37
G-6	+	—	.05
G-7	+	—	.03
G-8	+	—	.18
G-9	+	—	.15
G-10	+	—	.06
G-11	+++	+	.36
G-12	++	+[4]	.18
G-13	+	—	.12
G-14	+	—	.20
G-15	+	—	.22
G-16	+	+	.27
G-17	+	—	.13
G-18	+	—	.03
G-19	+++	+	.23
G-20	+++	+	.25
G-21	+++	+	.50
G-22	++	+[4]	.35
G-23	+++	+	.25
G-24	++	+[4]	.15
G-25	+++	+	.50

1. Qualitative estimation of pyocyanin in Sierra medium.
2. Iridescent material formed on 1% (w/v) glycerol-nutrient agar.
3. Optical density of chloroform extract of pyocyanin from overnight culture in Gessard's liquid medium with iron.
4. Iridescent material localized in pits on colony.

TABLE 3. Iridescence, Pyocyanin, and Pyocin Types of Selected Strains of *Pseudomonas aeruginosa*.

Source	Strain	Iridescence[1]	Pyocyanin[2] Production	Pyocyanin Production (iron)	Pyocin Type[4]
KSU lab stock	K24G	stimulated	++	++	8-17-39-577 8/39
porcine autopsy	K15G	none	+	+	8-17-39-577 8/39
chicken	K12G	entire	—	+++	8-39-8/39
bovine intestine	K110G	none	++	++	8-39-8/39
equine autopsy	K19G	pitted	+++	+++	8-26-577
bovine brain	K11G	none	++	++	8-26-577
procine autopsy	K18G	entire	—	+++	8-26-39-52 283-577-8/39
canine urine	K56G	entire	—	+++	8-10-39-52-283-577-584-593-8/39
canine ear exudate	K50G	entire	—	—	8-10-39-52 577-8/39

[1]Entire iridescence refers to a film of iridescent material over the whole colony. Pitted refers to iridescence in pits on the colony. Stimulated refers to iridescence formed when grown in the presence of glycerol.

[2]Pyocyanin formed on 2 percent glycerol-nutrient agar.

[3]Pyocyanin formed on 2 percent glycerol-nutrient agar with 0.001 percent ferric sulfate.

[4]Pyocin test strains used by Darrell and Wahba (6).

TABLE 4. The number of cells in colonies with and without the iridescent material.

Strain	colony age (hr)	iridescent[1] culture	% viable	non-iridescent[1] culture
K12G	60	156×10^7	82	185×10^7
	72	213×10^7	83	259×10^7
K19G	48	90×10^7	71	127×10^7
	72	202×10^7	90	222×10^7

[1]Average values of two trials.

whereas strain K19G formed the iridescent material only in pits within the colonies. These data showed that if the iridescent material was the result of lysis, it was less than ¼ of the population, when compared with the same culture grown on media that inhibited this substance. It should be noted that the viable count increased with the age of the colonies (Table 3), indicating that the cells were still multiplying and not totally lysed. Colonies isolated from these iridescent cultures displayed the iridescent material and had the same pyocin type as the parent culture.

Culture Viability. Four different strains on nutrient agar slants were examined during a 50 day period at 30C for viability. Two cultures were iridescent strains and two cultures were non-iridescent strains. All cultures were viable after the 50 day period, all retained the same pyocin types and all retained their ability or inability to form the iridescent material. From these results it was clear that non-iridescent variants did not take over the iridescent cultures and therefore the cells capable of producing the iridescent material were viable.

Isolation of Non-iridescent Cultures from Iridescent Strains. Methods used to cure bacterial cells other than *P. aeruginosa* of episomal elements failed after several trials to cure strains K12G or K19G of their pyocin types or the iridescent phenomenon.

Although non-iridescent colonies of the iridescent strains were isolated by streaking the cultures on nutrient agar with 10 mcg/ml demethylchlortetracycline (Lederle Laboratories, Pearl River, New Jersey), these were probably variants in the parent culture. These isolates retained the same pyocin type as the parent culture and did not revert to the iridescent form even after 1 year continuous transfer on nutrient agar slants.

Nutritional Requirements for the Iridescent Material. Fourteen selected strains were heavily inoculated on a mineral salts agar base which included adequate iron to permit growth and a useable carbon source. One strain, K50G would form the iridescent material only if the medium contained protein, anthranilate or tryptophan and glycerol. This organism was not a mutant requiring tryptophan or anthranilate for growth. With the exception of this strain, the organisms that produced the iridescent material formed this material on the same media as non-iridescent cultures producing pyocyanin. Sodium acetate, sodium pyruvate, sodium glutamate and alanine usually supported the production of the iridescent material.

DISCUSSION

Wensinck et al., (1967) showed that the iridescent material was essentially a pure substance that could be controlled by the iron concentration of the medium. Iron added to aerated liquid culture media is needed by some strains of *P. aeruginosa* for longevity of these cultures (Weinburg and Goodnight, 1970). Our results of the iridescent colonies grown on solid media indicated that the majority of the cells in colonies were alive and these colonies were capable of increasing in size with time. All colonies that were formed from cells of the iridescent colonies also displayed the iridescent phenomenon and had the same pyocin type as the parental culture. Even though the colonies of one strain were completely covered with the iridescent material, the cells under this substance were still capable of forming colonies. The strains of *P. aeruginosa* used in this particular experiment were chosen at random,

however, all iridescent cultures of this organism may not have the same survival patterns because *P. aeruginosa* cultures are often lysogenic (Paterson, 1965). The purpose of this study was to show that the iridescent material covering a colony did not mean the culture had totally lysed.

Pyocyanin appears to be an alternative secondary metabolite to the iridescent material when iron is present in the appropriate medium. Organisms that formed the iridescent material did so on the same medium as the non-iridescent cultures produced pyocyanin. Strains that produced large amounts of pyocyanin were invariably capable of forming the iridescent material, however, a few strains produced only the iridescent material and were apyocyanogenic.

In addition to the iridescent material and pyocyanin, *P. aeruginosa* produces other secondary metabolies including oxychlororaphin, phenazine-1-carboxylic acid and the aeruginosins (Holliman, 1961: Chang and Blackwood, 1968; Kocka, 1969). The formation of these substances depend upon several variables: aeration (Holliman, 1969), pH (Zierdt, 1971), temperature (Kocka, 1969), iron concentration (Wensinck et al, 1967), the stage of growth; Kocka, 1969) and the carbon source (Berk, 1963; Wensinck et al., 1967; Kocka, 1969).

The function of these substances has not conclusively been determined, although Mann (1970) and Korth (1971) indicated that pyocyanin and phenazine-1-carboxylic acid function as redox agents. It is notable that the formation of these secondary metabolites is favored in non-aerated or static conditions and that the carbon source is a determining factor as to which secondary metabolite will be formed.

Since a single strain of *P. aeruginosa* is capable of forming all or several of these secondary metablolites previously mentioned (Chang and Blackwood, 1968; Kocka, 1969) depending upon the cultural conditions, these substances may act as a detoxification mechanism in the phases of growth after logarithmic growth.

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SPECIES DIVERSITY OF BENTHIC MACROINVERTEBRATES AND LIMNOLOGICAL CONDITIONS IN A 1ST ORDER MOUNTAIN STREAM

by

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ABSTRACT.—Limnological conditions and species diversity were determined in a 1st order spring-fed mountain stream flowing through a sphagnum bog. Thirty-six species of aquatic invertebrates representing seven orders were collected during the study. Species diversity, ($\bar{H}$), and redundancy, (R), were similar to 4th order downstream stations.

Introduction

A number of systems have been proposed and utilized in the classification of streams. Most are based on such variables as velocity, source of water, gradient, etc. Kuehne (1962) and Harrel and Dorris (1968) used a system that was devised by Horton (1945) and modified by Strahler (1957). This system, which is more objective than others, designates the smallest unbranced tributaries in a drainage basin as 1st order streams. Where two 1st order streams join, a 2nd order stream is formed, and when two 2nd order streams join, a 3rd order stream is formed etc. Lower order streams flowing directly into higher order streams without passing through the hierarchy of tributaries do not affect ordinal designations.

In the present study, physicochemical conditions and species diversity of benthic macroinvertebrates were determined in a 1st order tributary of a mountain stream that flowed through a bog. Species diversity was determined by using information theory techniques.

Description of Study Area

Little Stony Creek, located completely in Giles County, Virginia, is a typical mountain stream with long riffles and short pools (Fig. 1). Based on the Horton and Strahler method of drainage analysis, Little Stony Creek ranks as a 4th order stream. The creek originated as a series of springs from the Clinch sandstone of Silurian age and flowed almost immediately into Big Soft Sleep Bog, a sphagnum bog of approximately 24.3 hectares (Mann, 1950). The direction of flow is southwesterly for approximately 19.4 kilometers were it joins the New River.

Methods

Seventeen bottom samples were taken with a Surber sampler during July of 1970 from a 1st order tributary of Little Stony Creek where it passes through the bog (Fig. 1). Samples were washed in a seive (U.S. Standard soil series with openings of 0.420 mm) and preserved in 70% isopropyl alcohol. Crayfish, which were present, were not collected. Alkalinity and dissolved oxygen were measured in the field according to standard methods. The pH was measured by means of a portable Sargent pH meter. Stream discharge was estimated by the method of Robins and Crawford (1954). Estimates of community structure were

obtained with Patten's (1962) equations where

$$(1)\quad H = \sum_{i=1}^{m} n_i \log_2 \frac{ni}{\overline{N}}$$

(Diversity per m^2)

$$(2)\quad \overline{H} = \sum_{i=1}^{m} \frac{ni}{\overline{N}} \log_2 \frac{ni}{\overline{N}}$$

(Diversity per individual)

$$(3)\quad Hmax = \log_2 N! - m \log_2 N/m)!$$

(Maximum diversity)

$$(4)\quad Hmin = \log_2 N! - \log_2 [N-(m-1)]!$$

(Minimum diversity)

$$(5)\quad R = \frac{Hmax - H}{Hmax - Hmin}$$

(Redundancy)

where (N) is the total number of organisms, (ni) number of individuals per species and (m) number of species in a unit area. Calculations were performed on an IBM 360 Model 40 data processing machine at the Bradley University Computer Center.

Results and Discussion

The dominant plant in Big Soft Sleep Bog was *Sphagnum* sp. The only aquatic invertebrates observed in the bog during the study were adult beetles represented by the family Dytiscidae. Mean oxygen concentration and pH were higher in the stream than in the bog (Table 1).

Thirty-six species of aquatic invertebrates representing seven orders were collected during the

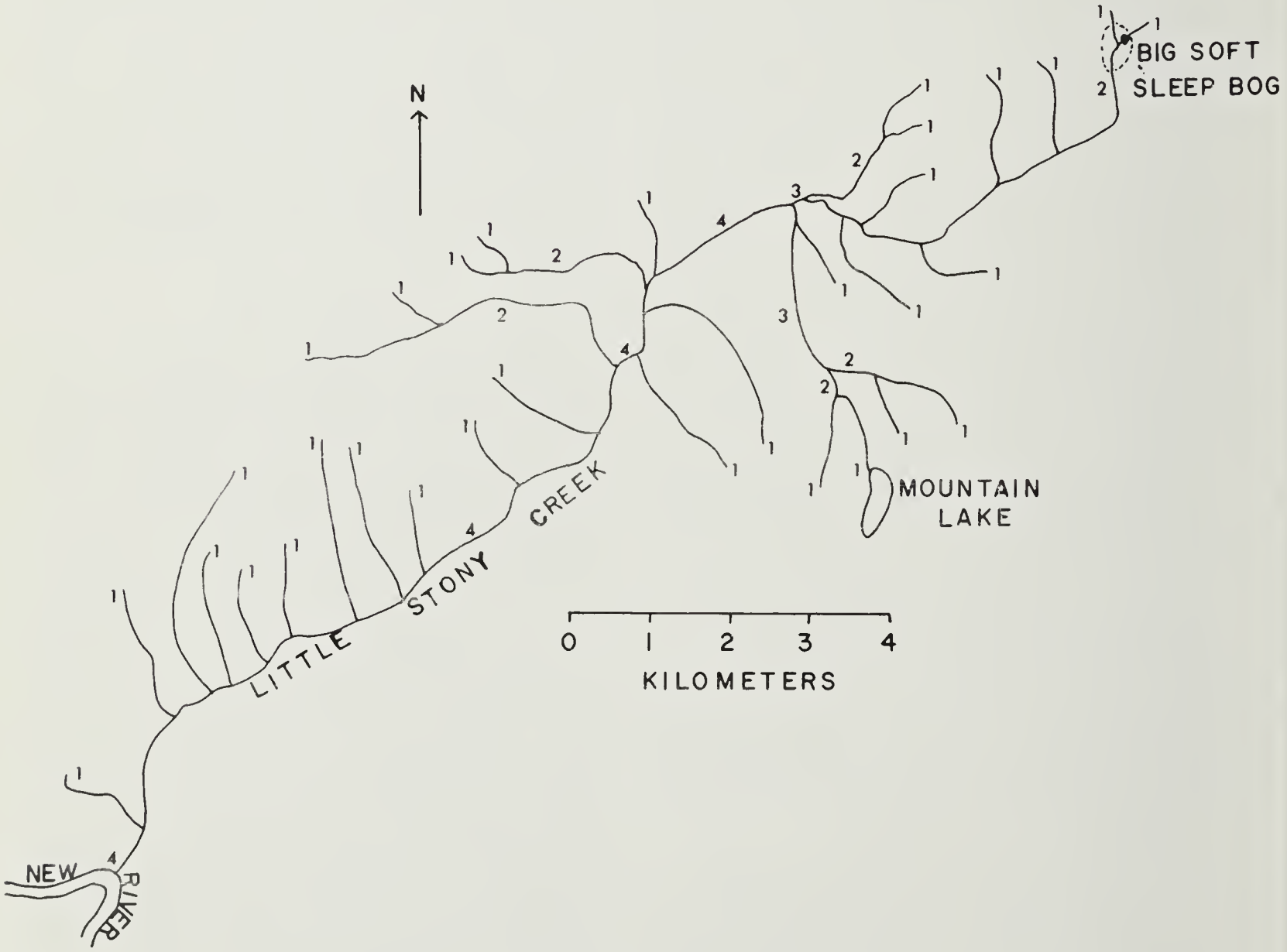

FIGURE 1. Map of Little Stony Creek. Sampling Station indicated by (●). Numbers indicate stream order classification.

study (Table 2). In an earlier study, Mathis (1968) reported the presence of 39 species and 679 individuals per m^2 at one station and 54 species and 1,660 individuals per m^2 at another in the lower reaches of Little Stony Creek. Both were 4th order stations. $\overline{H}$ ranged from 3.71 to 4.61 and R ranged from 0.17 to 0.29. Individuals in the orders Ephemeroptera, Odonata, Pelecypoda, Gastropoda, and Turbellaria, while present in lower reaches of the stream, were not represented in the bog area. Isopods, which were present in the bog area, were not collected at downstream stations in the earlier study.

The extant biota of any stream exhibits longitudinal succession and Little Stony Creek is no exception. The presence of an acid bog at the

TABLE 1. MEAN SUMMER PHYSIOCO-CHEMICAL CONDITIONS IN LITTLE STONY CREEK AND BIG SOFT SLEEP BOG

	Little Stony Creek	Big Soft Sleep Bog
O_2 (ppm)	7.4	1.8
pH	5.7	4.5
Temperature (C)	15	22
Conductivity*	8	44
Alkalinity (HCO^-_3)	8	—
Turbidity (ppm)	13	—
Discharge	.01 m^3/sec	—
Velocity	.43 m/sec	—

*umhos/cm^3 at 25C

TABLE 2. SPECIES DIVERSITY OF BENTHIC MACROINVERTEBRATES IN LITTLE STONY CREEK FLOWING THROUGH BIG SOFT SLEEP BOG*

Taxon	*Number of Species*	*Individuals/M^2*
Diptera		
Ceratopogonidae	2	35
Chironomidae	10	490
Tipulidae	4	10
Tabanidae	1	2
Oligochaeta	6	29
Trichoptera	7	160
Sialidae	1	18
Plecoptera	2	172
Isopoda	1	29
Coleoptera		
Dytiscidae	1	1
Elmidae	1	1
Total	36	947

*($\overline{H}$) Diversity per individual = 3.45; R (Redundancy) = .34

head of a stream is atypical, however, and has undoubtedly influenced the assemblage of organisms now inhabiting the stream, at least near the source and for some distance downstream. To what degree the bog affects longitudinal succession is unknown.

The rather diverse faunal assemblage that is found in Little Stony Creek is reflected by $\overline{H}$ and R (Table 2). The value obtained for $\overline{H}$, which reflects species diversity, was slightly lower than the lowest value reported in the earlier study (Mathis 1968) for the 4th order downstream stations. Concomitantly, R, a measure of the repetitious occurence of individuals, was only slightly higher than the maximum value recorded in the earlier study for 4th order downstream stations. In their study of a complete drainage basin, Harrel and Dorris (1968) reported a maximum summer value of 3.5 for $\overline{H}$ in a 5th order stream and a minimum value of 0.30 for R in a 3rd order stream.

The continuous flow of water from the spring at the source of the creek undoubtedly provided a stable environment that supported a rather complex faunal assemblage in view of what is generally found in 1st order streams. Harrel and Dorris (1968) did not report on 1st or 2nd order streams and collected only 38 species in 3rd order, 35 in 4th order, 53 in 5th order and 39 in 6th order streams during summer. Thus, in areas where 1st and 2nd order streams flow intermittently and pools occasionally dry up during summer, diversity is low. In 3rd, 4th, 5th, and 6th order streams where some water generally remains in pools during summer, diversity and redundancy similar to that in 1st order spring-fed mountain streams is observed.

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LIP MORPHOLOGY OF *ASCARIS SUUM* AS REVEALED BY SCANNING ELECTRON MICROSCOPY

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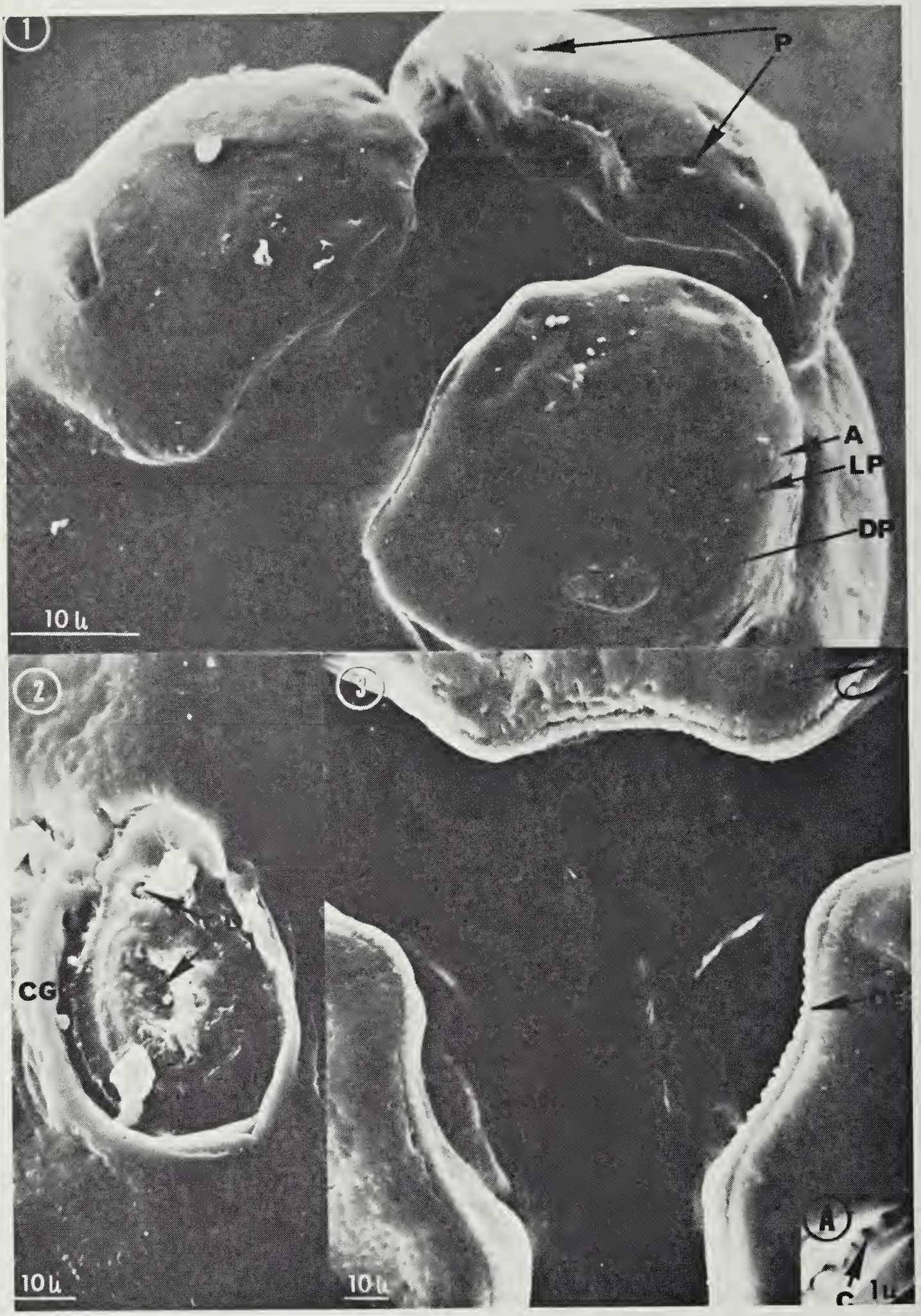
ABSTRACT.—Observations on the microtopographical detail of the labial morphology of *Ascaris suum* is presented.

The scanning electron microscope (SEM), an instrument capable of providing three-dimensional images because of the great depth of field possible with concomitant resolution and high magnification, has proved a valuable tool for examination of microtopographical detail of helminths when considering either host-parasite relationships or anatomical features of taxonomic significance. Hockley (1968) demonstrated the usefulness of the SEM in a study of the morphological adaptions of *Schistosoma mansoni* cercariae for host penetration. Other studies concerned with the surface features of *S. mansoni* as visualized with the SEM include the observations reported by Johnson and Moriearty (1969), Silk et al. (1969), Robson and Erasmus (1970), Race et al. (1970), Silk et al. (1970) and more recently Miller et al. (1972). Madden et al. (1970) utilized this technique in examining en face views of *Ascaris suum* and Allison et al. (1972) provided SEM micrographs on the anterior region of *Sulcascaris sulcatum* and *Cotylapsis insignis* confirming observations made with the light microscope and elucidating morphological detail heretofore unattainable by conventional techniques. Because labial morphology is considered a significant criterion in systematic nematology, the papillae and denticles of *A. suum* were restudied and observations on the microtopographical detail of these structures are reported herein.

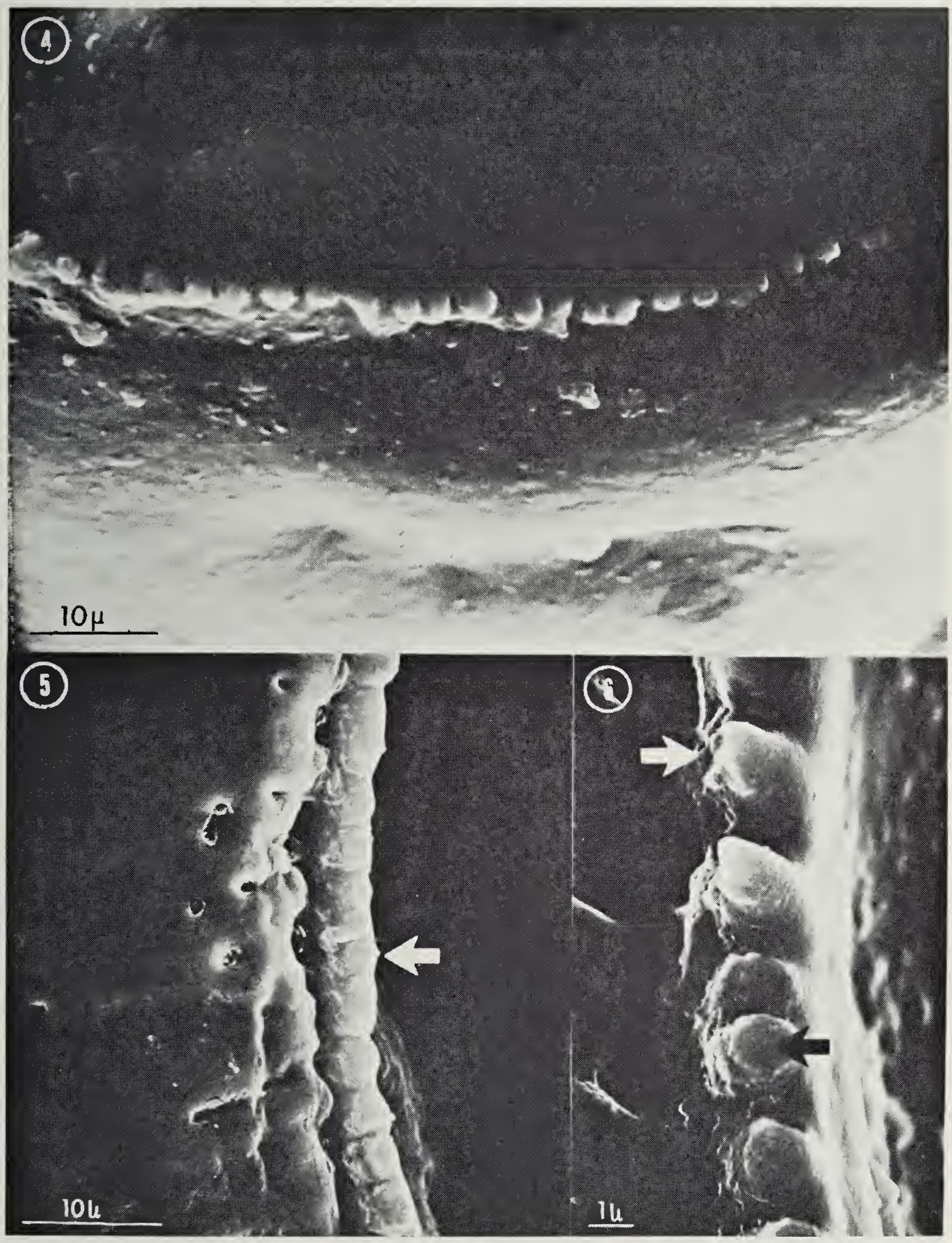
The methods for fixing, dehydrating, and supporting specimens of *A. suum* for the SEM were those reported by Madden et al. (1970). The surface of the specimens was rendered conductive by evaporating a layer (approximately 500 Å) of gold-palladium alloy (4:6) on to them in a vacuum evaporator fitted with a wobbler table to insure even coating. Specimens were examined in a Cambridge Stereoscan Mark IIA SEM at an accelerating voltage of 20 kv, 160 micro Amps beam current and a 100 micron final aperture.

The oral region of *A. suum* is characterized by a single dorsal and two ventrolateral lips surrounding the somewhat triangular mouth (Fig. 1). The inner circle of labial papillae are wanting and only small pits (two per lip) are discernible. The cuticle covering each double papilla of the outer circle appears as a raised mound surrounded by a cuticular groove. Two double papillae are visible at the base of the dorsal lip and one each on the ventrolateral lips. A small lateral papilla of the outer circle and an amphid are shown on the left ventrolateral lip.

According to Bird (1971), the outer labial and cephalic sense organs of the double papillae are stalked structures which appear to be capable of some movement. His light photomicrographs showed the labial and cephalic organs retracted and the circular canals which they oc-



FIGURES 1-3.—Scanning electron micrographs of the lips of *Ascaris suum*. 1. Entire head showing dorsal lip (D), ventrolateral lips (V), pits (P) of the inner circle, double papilla (DP) and a lateral papilla (LP) of the outer circle, and an amphid (A) X 135. 2. Double papilla with cuticular depressions (CD) surrounded by cuticular groove (CG) X 950. 3. Mouth opening with dentigerous ridges formed by rows of denticles (DE) on inner surface of each lip. Small cavities (C) on dentigerous ridge indicating the absence of teeth X 540. Insert A (enlarged portion of Fig. 3) illustrating cavities X 1100.



FIGURES 4-6.—External microtopography of the dentigerous ridge of *A. suum*. 4. Lip surface showing irregular arrangement of denticles X 1100. 5. Molar teeth forms showing small points (indicated by arrow) on the top surface of some denticles X 2200. 6. Dentigerous ridge showing conoid-shaped denticles (white arrow) and denticles flattened at the apex (black arrow) X 5600.

cupied when extended revealed. A higher magnification micrograph of a double papilla (Fig. 2) revealed two cuticular depressions encompassed by the cuticular groove. Only one of the worms examined showed this condition and in the single specimen shown here only one of the double papilla revealed a retracted cuticle. Whether this is a surface distortion due to the preparative technique employed or whether the cuticular covering is actually capable of retraction is difficult to interpret at this early stage in SEM studies.

Sprent (1952) described the denticles of *A. suum* as equilateral triangles with straight sides and rounded apices. Abdulrachman and Joe (1954) emphasized that Sprent's article gave the impression that this condition was constant. The dentigerous ridges formed by a conspicuous row of denticles on the inner surface of each lip are shown in Figures 3-6. As shown in Figure 3, the denticles of the dorsal and right ventrolateral lips of this particular specimen appeared uniform and resemble the "molar teeth" forms described by Abdulrachman and Joe (1954). At higher magnification, (Fig. 5) some of the molar teeth forms were flat on top while others contained small points (indicated by arrow).

Ubelaker and Allison (1972) described the denticles of *A. Suum* as regular in distribution and conoid in shape. The arrangement of the denticles along the ridge of some specimens was irregular and noticeably different in size (Fig. 4). Some of the denticles of the anterior portion of the dorsal lip were absent as noted by the presence of small cavities along the ridge (Fig. 3A). Denticles that were conoid-shaped were also observed and some were flattened at the apex, possibly by wear (Fig. 6).

To date there has been a paucity of observations made on the labial morphology of *A. suum* with the SEM. Now that this instrument is becoming increasingly available to more workers, examination of specimens from several geographic regions should prove valuable in determining the extent of morphological variation of the denticles.

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RESPONSE OF *ANOLIS CAROLINENSIS* TO ELECTROANESTHESIA

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ABSTRACT.—Fifty-two specimens of *Anolis carolinensis,* varying in weight from 0.5 to 4 grams, were anesthetized by electrical current. The range of current was 1 to 4 ma. and the range of voltage was 3 to 28.5 volts at 700 Hz. Ninety-eight percent of the specimens in a single constant environment were induced to change their color in a period of five minutes exposure to the electroanesthetic current. The cause may be a neural stimulation of the adrenal glands, releasing catecholamines. As a result of electroanesthesia, the recovery of the righting reflex was delayed which suggests an interruption in the nervous system.

Electroanesthesia (E.A.) is a technique to produce deep surgical anesthesia by application of electrical current to a subject. Since early experiments in 1875 (Smith, 1963), many animals and even man have been anesthetized with electrical current. Northway (1969) described the effects of electroanes thesia upon green iguanas and noted that these animals changed from a green to yellow color while they were anesthetized. *Anolis carolinensis,* a species of lizard studied often for experimental purposes, has a similar ability to change color spontaneously, over a wide range of greens and browns, as an adaptation to changing environmental stresses. Its responses to electroanesthetic currents were studied here, with attention directed to the biologic pathways through which E. A. exerts its effects.

Materials and Methods

Fifty-two (52) specimens of *Anolis carolinensis,* obtained from the Louisiana Biological Center in Norco, Louisiana, and varying in weight from 0.5 to 4 grams, were anesthetized with a Hewlett-Packard current generator, Model 3308B.

Almost all animals were green in color prior to electroanesthesia. A few which were brown were placed on a light green background until they adapted to light green. At that point the E.A. was given, using stainless steel pin electrodes inserted subcutaneously on either side of the head posterior to the eyes. Righting and withdrawal reflexes were tested before each experiment.

Induction of deep anesthesia occurred in 1 to 1-½ minutes, utilizing a 700 Hz. alternating current at 3 to 28.5 volts and 1 to 4 milliamperes. A loss of the corneal reflex and of the withdrawal reflex when a pinching stimulus was applied to the toes, feet, and legs occurred directly after application of the current. The stimulus was maintained for five minutes. At its terminiation, the corneal, righting and withdrawal reflexes were tested. Color changes were recorded.

Results and Discussion

Color changes occurred within 2 to 5 minutes, with a mean of 4.06 ± 0.84 minutes (Table 1). All lizards turned deep brown. The change in coloration began during electroanesthesia; it occurred first on the head near the electrodes, with subsequent mottling along the spine and legs. Post-orbital darkening was immediate. The entire body gradually became mottled and then brown.

Kleinholz (1938) applied a direct current to an *Anolis* lizard that had been hypophysectomized. This re-

TABLE 1. Power Factors Involved in Electroanesthesia of *Anolis carolinensis* and the Time Needed for Biologic Color Changes.

	Mean Values		S.D.
Current Necessary to Induce Deep Anesthesia	2.32	Milliamperes	0.62
Voltage to Induce Deep Anesthesia	9.58	Volts	5.60
Resistance to Electrical Current at Full Induction	6018.	Ohms	2886
Power at Full Induction	23.5	Milliwatts	16.4
Time Following Current Application to Turn from Green to Brown Color	4.06	Minutes	0.84

sulted in post-orbital darkening and a generalized mottled pattern that persisted for at least 20 minutes after stimulation. Kleinholz autotransplanted the post-orbital patches onto another region of the same *Anolis,* and darkening occurred again upon electrical stimulation. This indicated that such darkening is not under direct nervous control. Injection of epinephrine into hypophysectomized lizards also caused mottling. When electrical stimulation was given to hypophysectomized, adrenalectomized lizards they did not mottle. Perhaps activation of the adrenal medulla, through the intermediation of the nervous system, produces changes in pigment color.

There was no delay in the righting reflex of any of the 52 unanesthetized controls (0± 0 minutes, arbitrarily). All righted themselves at once and in most cases resisted being placed on their back. All 52 experimental animals, however, showed a significant delay (4.05 ± 2.32) after termination of E.A. Despite the loss of the righting reflex, the experimental animals immediately responded by a withdrawal reflex of the feet when the toes were pinched.

Although inadequately studied, equilibratory systems are present in all reptiles (Gans, 1970). On the assumption that the *Anolis*' mechanism for righting is similar to other known righting reflex mechanisms, the data indicate that the current induced an interruption in the nervous system, particularly the postural centers (e.g. the basal ganglia). In theory, postural receptors were stimulated at the thoracic and lumbar segmental levels of the spinal cord. These receptive sites correspond to the points of contact between the animal and the surface on which it is placed. Such impulses radiate up the cord to higher receptive centers in the cerebral cortex, and this provides the animal with a consciousness of what has occurred. The postural receptors of the ear simultaneously send impulses through the 8th cranial nerve to receptive brain nuclei; these impulses are then radiated into areas 4 and 6 of the cerebral cortex. In response, the animal not only sends impulses through the pyramidal system to right itself, but also simultaneously sends adjunctive postural responses from area 6 of the cortex to the basal ganglia.

On the basis of the foregoing assumptions, and in the light of the observed delay in reflex response, the results of this experiment add support to work of Pozos et al.,

(1969), who concluded that the basal ganglia are involved among the sites for producing anesthesia.

The presence of the withdrawal reflex after termination of E.A. suggests that this reflex involves a segmental transmission through restricted levels of the spinal cord, the brain not being significantly involved. Although this reflex is absent during E.A., the spinal centers for this reflex are apparently active at the termination of E.A.

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A COMPARISON OF THE FOOD INTAKE OF MALE AND FEMALE CHANNEL CATFISH (*ICTALURUS PUNCTATUS*)

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ABSTRACT.—A study was conducted to determine the relationship between food intake and sex of yearling channel catfish. The work was conducted in cages and involved the evaluation of the response of 494 fish. No significant difference was found to exist between the amount of food consumed and the sex of the fish.

A problem associated with the intense culture of fish is variation in growth. This has been partly attributed to sexual differences (Albaugh, 1969 and Heidinger, 1970). Beaver et al. (1966) attributed greater growth of male channel catfish, as compared to females, to a sex-linked genetic characteristic that gave males an advantage either through aggressive feeding behavior or through efficiency of food conversion. To date, the relationship between ration consumed and sex of channel catfish had not been investigated.

Materials and Methods

To investigate the feeding response of male and female channel catfish an experiment, utilizing cage culture techniques, was initiated during the summer of 1970. Yearling channel catfish, with a mean weight of 29.3 g, were utilized in the study. The experiment was conducted in an earthen pond of the Cooperative Fisheries Research Laboratory located at Southern Illinois University. This research pond has an area of 0.06 ha and a depth of 1.25 m. The pond received a flush of approximately 75 liters of water per minute obtained from a 32 ha city reservoir.

Nine cages of a cylindrical design were used in the study. Cages were 0.61 m in diameter and 1.22 m in depth and were constructed of 16-gauge welded wire with a mesh size of 1.27 x 2.54 cm; they were treated with a tar compound to avoid zinc toxicity. A 25.4 cm strip of aluminum screen wire was installed at water line to prevent food from floating out of the cages. Tops and bottoms of the cages consisted of exterior plywood 1.9 cm thick. When floated by styrofoam blocks, each cage contained approximately 0.27 m^3 of water.

Nine cages were stocked with channel catfish on June 19 at a rate of 222.2 fish per m^3. The suggested rate of stocking for channel catfish is 196.2-261.6 fish per m^3 (Lewis, 1969). Fish were cultured in cages from June 19 to July 14, 1970, a period of 26 days. This time was necessary to acclimate the fish to cage conditions and to establish the feeding response of the catfish. Food used in the study was a floating food for trout (Purina Trout Chow) containing a crude protein content of not less than 40.0 per cent and measuring 6.0 mm in size. The ration for fish in each cage was weighed and transferred to labeled containers for distribution to the respective cages. Fish were fed daily at twilight an amount of food equal to three per cent of their body weight.

After a 20 minute feeding period on the final day of the experiment, the fish were killed and removed from the cages, sealed in airtight containers and immediately frozen.

The length of storage prior to laboratory analysis was two weeks.

Fish were thawed for analysis, weighed to the nearest gram, and sexed. The contents of the gut anterior to the pyloric sphinctor were removed, and the fish weighed again. Food was placed in pre-weighed dishes and oven-dried at 100°C for 24 hours or until a constant weight was obtained. Contents were then weighed to the nearest 0.0001 g. Per cent body weight was then calculated using dry weight of food and wet weight of fish.

Data were programmed using the multiple regression approach (Kelly et al., 1969) and were submitted to the Southern Illinois University Data Processing and Computer Center for analysis. Statistical procedures used in the study followed Edwards (1960).

RESULTS AND DISCUSSION

A total of 494 fish were examined; of these, 53.8 per cent were males compared to 46.2 per cent females. The greatest ration consumed by a fish was equivalent to 4.1 per cent of its body weight. Only three fish examined contained no measurable amount of food.

The mean food intakes of male and female channel catfish within the nine experimental cages were compared (Table 1). No significant difference (P=.05) was found to exist between the rations consumed by males compared to females. Beaver et al. (1966) concluded that a sex-linked genetic characteristic gave male channel catfish an advantage either through efficiency of food conversion or through aggressive feeding behavior. Data gathered from the current study showed that, at least for yearling channel catfish, sexual difference had no relationship to ration consumed. In comparing the food intake of male and female bluegill sunfish (*Lepomis macrochirus*) Heidinger (1970) found no significant difference in per cent stomach contents between sexes. Differences in growth were attributed to quality of food or to a decrease in efficiency in digestion or assimilation of food by female sunfish.

TABLE 1. Comparison of mean food intakes, expressed as per cent of body weight, of yearling male and female channel catfish cultured in cages.[1]

Cage	Male			Female			t-value for Males vs. Females
	Number of Individuals	Mean	SD	Number of Individuals	Mean	SD	
1	27	0.8	0.59	19	0.7	0.42	0.620 n.s.[2]
2	30	1.3	0.68	25	1.0	0.73	1.547 n.s.
3	28	1.5	0.68	27	1.6	0.66	-0.543 n.s.
4	32	0.6	0.38	24	0.7	0.38	-0.957 n.s.
5	30	0.5	0.39	24	0.6	0.49	0.820 n.s.
6	32	1.3	0.60	25	1.6	0.77	-1.623 n.s.
7	33	1.6	0.83	24	1.5	0.77	0.455 n.s.
8	24	2.0	0.76	34	2.2	0.68	1.032 n.s.
9	30	2.3	0.86	26	1.9	0.86	1.635 n.s.

[1]Food intakes based on dry weight of food divided by wet weight of fish and multiplied by 100.

[2]n.s. = no significant difference at the .05 level of probability.

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WOODY VEGETATION SURVEY OF ROCKY BRANCH NATURE PRESERVE, CLARK COUNTY, ILLINOIS

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ABSTRACT.—The vegetation of the Rocky Branch Nature Preserve is a typical example of the forests associated with the dissected Illinoian till of East-Central Illinois. It has a composition of 128 stems per acre (4" and above in diameter) with a basal area of 69 square feet. Of the 62 woody species present on the site, 28 are canopy trees, 13 are understory trees, and 21 are shrubs and vines. White Oak, the dominant species, comprises one-third of the total individuals and nearly one-half of the total basal area. It is followed in order of importance by black oak, sugar maple, red oak, shagbark hickory, pignut hickory, mockernut hictory and bitternut hickory. The site contains three well defined vegetation zones. The first zone is a mature upland forest dominated by white oak, the second is a lowland forest dominated by sugar maple, sycamore, slippery elm and black walnut and the third is second growth upland with white and black oak comprising more than 50% of the stand. A sapling and seedling survey indicates that sugar maple will become more important in the future.

Rocky Branch Nature Preserve is a 130-acre woodlot in which are found the forests typically associated with the Illinoian till of East-Central Illinois. The preserve, which is located in Clark County about six miles northwest of Marshall, Illinois, was purchased by the Nature Conservancy and is now under the trusteeship of Eastern Illinois University. The area is interesting botanically due to the appearance of many species of plants that are uncommon to this part of Illinois.

A few ecological and taxonomic studies have previously been conducted in the preserve. Stover (1930) made a checklist of the plants that occurred here and gave short descriptions of the common plant associations. A study of the bryophytes was undertaken by Vaughn (1941) and later by Arzeni (1947), while Hellinga and Ebinger (1970) completed a checklist of the vascular plants found in the preserve. The most recent ecological study completed was a survey of a 16-acre tract of mature timber to the west and separated from the rest of the preserve (Ebinger and Parker, 1969). In this survey, 36 woody species were found growing in the area with white oak being the most important, comprising one-half of the basal area and one-third of the total individuals.

Description of the Woodlot

The eastern part of the Rocky Branch Nature Preserve, in which this survey was undertaken, is located in Section 29, T12N, R21W, Clark County, Illinois. Topographically, it is much the same as the western area (Ebinger and Parker, 1969) with a high variability in slope and relative relief. The maximum variation in elevation is 73 feet, the highest point being the south-east corner at 648 feet above sea level.

The area is drained by two main streams. One, Rocky Branch Creek, is in the western half of the woodlot and divides the area into two main vegetation zones. This creek flows in a north-easterly direction, and empties into Big Creek, the second major stream, which forms the northern boundry of the preserve. Sandstone outcroppings result in 20- to 50-foot bluffs along both of these streams.

The western part of the area studied, west of Rocky Branch

Creek, is flat to gently rolling upland. This area is in relatively mature, undisturbed forest. Except for a few acres of lowland forest along Rocky Branch Creek and Big Creek, the remainder of the preserve, to the east of Rocky Branch Creek, is rolling upland. This area is in second growth forest, though two small fields are located along the flat ridges near the southern edge of the area. This entire area is dissected by small intermittent streams that create shallow to occasionally deep ravines.

Of the 130 acres in the preserve, only 70 acres were included in this study. An area of approximately 20 acres in the south-west corner of the nature preserve is highly disturbed, and to the south-east is 9 acres of open field. To the north-east is a 20-acre area of highly dissected upland. Owing to the irregular shape of this area, it would have been extremely difficult to set up any meaningful quadrats. Also, a 10-meter edge was set aside on the western, southern and eastern borders of the area to account for edge effect. This, together with a northern edge of steep, sandstone bluffs which border Big Creek, accounted for another 11 acres.

METHODS

The woodlot was surveyed and marked off into quadrats that were 50 meters on a side (0.61776 acres); each quadrat was then divided diagonally into quarters to facilitate surveying the vegetation. The number, size and species of all trees above 4 inches d.b.h. were recorded for each of the quadrats. Diameters were recorded to the nearest 1/10 of an inch. Dead standing and dead down trees were measured and identified when possible. Trees displaying coppice growth were treated in much the same way as other trees; the species were identified and the number and d.b.h. of the stems were recorded. In the analysis of the data each stem of a coppice tree was considered a separate individual.

The Importance Value (IV) was calculated from the field data to provide a better basis for comparison of the various species. The determination of the IV followed methods outlined by McIntosh (1957) and later by Boggess (1964) in which the IV is the sum of the relative dominance:

$$\frac{\text{basal area of a species}}{\text{basal area of all species}} \times 100$$

and the relative density:

$$\frac{\text{number of individuals of a species}}{\text{number of individuals of all species}} \times 100$$

In each 50 meter quadrat, four 1/100 and 1/1000 acre, nested, circular plots were randomly located. The saplings (1- to 4-inches d.b.h.) were tallied on the larger plot and the seedlings on the smaller. The seedlings were divided into those under one foot in height and those over one foot in height but less than one inch in diameter.

The taxonomic nomenclature used in this paper follows that of Ebinger and Thut (1970).

RESULTS AND DISCUSSION

A total of 62 woody species was found in the woods. Of these 28 were canopy trees, 13 were understory trees and 21 were shrubs or vines. The more important species encountered with their density and frequency by height and diameter appear in Table 1. In this table, the species which had extremely low density and frequencies are grouped together under the category of "others". The species symbols are used to identify the species in subsequent tables. The 11 leading species encountered with their relative

TABLE 1.—Density per Acre and Frequency of Woody Species by Height or Diameter Class. The species symbol will be used to identify species in subsequent tables.

Scientific Name	SYMBOL	Height Class Density			Height Class Frequency %		Diameter Class 1"-4" d.b.h.		Diameter Class 4"+d.b.h.	
		<1'	>1' <1" d.b.h.	Total	<1'	>1' <1" d.b.h.	Density	Frequency %	Density	Frequency %
CANOPY TREES										
Quercus alba L.	WO	162	138	300	10.8	10.0	14.6	9.4	40.00	98.2
Quercus velutina Lam.	BO	264	124	388	19.7	10.4	12.2	9.6	17.41	94.7
Acer saccharum Marsh	SM	1,990	423	2,413	44.7	20.3	45.0	18.9	10.91	77.3
Quercus rubra L.	RO	58	69	127	4.3	5.9	3.9	3.7	6.38	79.1
Carya ovata (Mill.) K. Koch	SH	128	167	295	9.6	12.9	22.4	14.6	8.90	92.1
Carya glabra (Mill.) Sweet	PH	222	73	295	15.9	5.1	2.6	2.6	5.54	80.0
Carya tomentosa (Poir.) Nutt.	MH	38	96	134	2.6	7.7	22.6	13.8	6.31	81.7
Carya cordiformis (Wang.) K. Koch	BH	139	45	184	10.6	3.9	5.1	4.1	3.23	54.7
Ulmus rubra Muhl.	SE	256	555	811	13.1	20.8	16.3	9.1	3.42	59.1
Sassafras albidum (Nutt.) Nees	Sa	488	193	681	19.2	12.7	17.9	7.5	3.83	53.0
Fagus grandifolia Ehrh.	Be	53	10	63	4.5	0.9	1.0	0.8	1.69	25.2
Juglans nigra L.	BW	2	2	4	0.2	0.2	1.0	1.0	2.04	48.6
Prunus serotina Ehrh.	BC	266	106	372	16.5	8.3	3.7	3.1	2.16	48.6
Platanus occidentalis L.	Sy	—	—	—	—	—	0.2	0.2	1.41	20.2
Fraxinus americana L.	WA	758	156	914	28.3	8.3	2.2	1.8	1.74	41.7
Liriodendron tulipifera L.	TT	14	8	22	1.2	0.2	1.0	0.5	1.13	14.7
Nyssa sylvatica Marsh	BG	34	26	60	2.3	1.9	5.1	2.4	1.21	26.0
Quercus imbricaria Michx.	SO	86	30	116	6.8	2.7	0.4	0.4	2.04	42.6
Acer negundo L.	BE	—	2	2	—	0.2	1.4	1.0	1.04	13.9
Ulmus americana L.	AE	10	57	67	0.9	3.1	4.3	3.3	.64	20.0
Juglans cinerea L.	Bu	2	—	2	0.2	—	0.2	0.2	.64	14.7
Tilia americana L.	AL	—	—	—	—	—	0.6	0.2	.49	11.3
Celtis occidentalis L.	Ha	13	8	21	1.3	0.7	1.6	1.2	.41	12.1
Others		2	6	8	—	—	0.2	—	.72	—
UNDERSTORY TREES										
Ostrya virginiana (Mill.) K. Koch	Ir	939	234	1,173	32.2	12.5	20.3	12.0	1.93	37.3
Carpinus caroliniana Walt.	BB	309	127	436	11.0	6.8	22.2	6.1	1.21	24.3
Cercis canadensis L.	Re	37	7	44	3.1	0.7	1.6	1.2	.30	6.0
Cornus florida L.	FD	232	183	415	12.2	11.4	30.9	17.7	.26	14.7
Morus rubra L.	RM	12	17	29	0.7	1.5	0.6	0.6	.19	6.9
Amelanchier arborea (Michx.f.) Fern.	Ju	45	11	56	1.9	1.1	2.6	2.0	.09	5.2
Others		4	13	17	—	—	0.2	—	.27	—
WOODY SHRUBS AND VINES										
Rhus radicans L.		673	448	1,121	17.5	10.2	—	—	—	—
Rubus allegheniensis Porter		98	574	672	5.3	15.7	—	—	—	—
Euonymus obovatus Nutt.		419	—	419	4.3	—	—	—	—	—
Corylus americana Walt.		63	198	261	3.1	7.2	0.2	0.2	—	—
Staphylea trifolia L.		108	131	239	21.2	25.7	1.2	0.8	—	—
Rosa carolina L.		167	66	233	6.6	2.3	—	—	—	—
Celastrus scandens L.		130	80	210	8.2	3.7	—	—	—	—
Rhus glabra L.		24	177	201	0.3	4.9	—	—	—	—
Ceanothus americanus L.		8	143	151	0.7	5.9	—	—	—	—
Euonymus atropurpureus Jacq.		93	23	116	18.1	4.5	—	—	—	—
Viburnum prunifolium L.		26	72	98	0.9	1.7	—	—	—	—
Rubus occidentalis L.		6	64	70	0.5	2.3	—	—	—	—
Hydrangea arborescens L.		6	57	63	0.5	1.9	—	—	—	—
Others		23	128	151	—	—	2.7	—	—	—
TOTAL		8,407	5,047	13,454	—	—	268.0	—	127.54	—

values and number of individuals and basal area per acre in broad diameter clases are included in Table 2.

Of the aborescent species found at Rocky Branch, the oaks (white, black and red) rank first, second and fourth in importance, respectively, and comprise the most important species group in the woodlot. White oak, with an IV of 76.2, comprises nearly one-half of the basal area and one-third of the total individuals in the area studied. It exceeds all other species in all broad diameter classes. This species is considered the leading dominant in all sections of the woodlot except the small lowland areas adjacent to Big Creek and Rocky Branch Creek.

Black and red oak, together, have an IV of 38.5 with black oak ranking second to white oak throughout the hillside and upland areas of the woodlot. Both species have a relatively good size class distribution, with a majority of the individuals appearing in the 4- to 6- and 7- to 12-inch diameter classes. Black oak has a good showing among the saplings and seedlings, and is better represented than is white oak. Red oak has a relatively poor representation of saplings and seedlings.

The second most important species group in the woods is the hickories. The group is represented by shagbark, pignut, mockernut and bitternut hickories which rank fifth, sixth, seventh and eighth respectively. Shagbark and mockernut hickories are well distributed throughout the area, with respective frequencies of 92.1 and 81.7 percent. Although pignut hickory is not as well distributed throughout the woodlot, its more common occurrence in the larger diameter classes makes this species, overall, more important than mockernut hickory. Of the four species of hickory represented bitternut is the most restricted, with a relative frequency of only 54.7 percent. Pignut is the only species of this genus with members in the 25 inch or greater diameter class.

The third most important species in the woodlot is sugar maple. With an IV of 15.8, this species accounts for approximately one-tenth of the basal area and one-tenth of the total individuals per acre in the woodlot. More than one-half of the individuals of sugar maple occur in the 4- to 6-inch diameter class and none in the 25-inch or greater diameter class. This species is not evenly distributed throughout the woods. It ranks first in importance in the lowland area around Rocky Branch Creek and is also common on the more mesic hillsides. Sugar maple has a greater number of saplings and seedlings per acre tha nany other species or species group in the woods.

Slippery elm, sassafras, beech, black walnut and sycamore are scattered throughout the more mesic parts of the woods, but have Importance Values of less than 5. Most of these species are more common in the lowlands surrounding Rocky Branch and Big Creeks. Few seedlings and saplings of black walnut and sycamore occur in the sample plots and both have poor size-class distribution, indicating that they will decrease in importance in the future. Slippery elm and sassafras, in contrast, have much better size-class distribution and are well represented in the seedling and sapling categories. Both species are extremely common in the lowlands but small diameter trees as well as seedlings and saplings are not uncommon in the upland areas. Very few individuals of these species were found above the 4- to 6-inch diameter class. Beech is common on the relatively steep slopes and lowlands surrounding Rocky Branch Creek but occurs very rarely in the remainder of the

TABLE 2.—Number of Trees, Basal Area per Acre and Importance Value (IV) of the Eleven Leading Dominants.

	4-6 inches		7-12 inches		13-18 inches		19-24 inches		25 + inches		Total		Percent Total		
Species	No.	B.A.	No.	B.A.	No.	B.A.	No.	B.A.	No.	B.A.	No.	B.A.	Rel. Den.	Rel. Dom.	I.V.
WO	11.03	1.80	15.23	8.41	11.94	15.89	1.56	3.73	0.24	1.09	40.00	30.92	31.4	44.8	76.2
BO	7.63	1.20	6.89	3.51	2.41	3.17	0.37	0.91	0.11	0.53	17.41	9.32	13.7	13.5	27.2
SM	5.50	0.82	3.81	1.87	1.44	1.90	0.16	0.40	...	...	10.91	4.99	8.6	7.2	15.8
RO	2.37	0.37	2.46	1.35	1.14	1.52	0.34	0.87	0.07	0.27	6.38	4.38	5.0	6.3	11.3
SH	5.93	0.93	2.63	1.26	0.33	0.38	0.01	0.03	...	...	8.90	2.60	7.0	3.8	10.8
PH	1.49	0.24	2.81	1.56	1.19	1.47	0.04	0.10	0.01	0.06	5.54	3.43	4.3	5.0	9.3
MH	4.11	0.62	1.86	0.90	0.33	0.39	0.01	0.03	...	...	6.31	1.94	4.9	2.8	7.7
BH	1.56	0.24	1.36	0.68	0.30	0.36	0.01	0.03	...	...	3.23	1.31	2.5	1.9	4.4
SE	2.27	0.33	0.94	0.40	0.20	0.24	0.01	0.03	...	...	3.42	1.00	2.7	1.5	4.2
Sa	3.16	0.43	0.64	0.26	0.03	0.03	...	...	...	...	3.83	0.72	3.0	1.0	4.0
Be	0.59	0.09	0.63	0.32	0.40	0.56	0.06	0.12	0.01	0.07	1.69	1.16	1.3	1.7	3.0
Others	12.05	1.82	6.30	2.94	1.24	1.54	0.27	0.68	0.06	0.26	19.92	7.24	15.6	10.5	26.1
TOTAL	57.69	8.89	45.56	23.46	20.95	27.45	2.84	6.93	0.50	2.28	127.54	69.01	100.0	100.0	200.0

woods. The mesic site preference of this species as well as the small number of seedlings and saplings indicates that its importance will probably not increase in the woods.

To better analyze the stand data, the woods was divided into three zones based on the topography and age of the timber. Although these three zones are in part artificial, they do allow a more accurate analysis of the species distribution and ecological relationships. These zones are: a mature upland forest to the west of Rocky Branch Creek, a small area of lowland forest immediately surrounding Rocky Branch and Big Creeks, and a second growth upland forest to the east of Rocky Branch Creek. The number of trees and basal area per acre, relative values and Importance Value for the 10 leading species in each zone are shown in Table 3. The vegetation of the steep hillsides on both sides of Rocky Branch Creek is included with the upland data.

Mature Upland Forest.—The area to the west of Rocky Branch Creek is a dry, relatively flat upland dissected by a few shallow ravines. White oak is the dominant species with an Importance Value of 110. The IV of this species exceeds 100 on all quadrats of this zone and on some exceeds 160. Over 80 percent of the white oaks are in the 7- to 12- and 13- to 18-inch diameter classes. Black and red oaks rank second and fourth in importance and are most common in the more mesic parts of the upland forest. As a group, the three oak species comprise 63 percent of the total number of trees and 77 percent of the stand basal area. The oaks are well represented in the seedling category with white oak averaging 398 seedlings and 8 saplings per acre while the total for black oak are 363 seedling and 10 saplings.

Pignut hickory is a common associate of the upland forest (third in IV) while the other hickory species have much lower importance values. The more mesophytic sugar maple, beech and slippery elm are also scattered throughout this zone. Slippery elm exceeds all other trees in seedlings with 2023 per acre while sugar maple exceeds all other species in saplings with 64 per acre. Sassafras, which is not included among the top ten in importance is also well represented in the seedling and sapling categories. This species averaged 852 seedlings and 30 saplings per acre in the mature upland forest.

Lowland Forest.—The lowland forest is in scattered areas along Big Creek and some of its tributaries with its best development surrounding Rocky Branch Creek. Here, sugar maple is the most important species with an IV of 36. Sycamore is second in importance followed by slippery elm and black walnut. The lowland forest is the smallest zone recognized in the woods yet it contains the greatest number of species. The great diversity of species found here and the relatively high importance of these minor species is indicated by the IV of the "others" category which is almost twice that of sugar maple, the leading dominant. The more important of these "minor" species are white walnut, tulip tree, american elm, hackberry and ironwood.

Regeneration of woody species is much higher than in other zones of the woods with the species in this zone averaging 20,728 seedlings and 484 saplings per acre. A few of the dominant species have excellent regeneration with sugar maple averaging 4,642 seedlings and 77 saplings, slippery elm with 1029 seedlings and 77 saplings and blue beech with 1957 seedlings and 144 saplings per acre. The remainder of the

TABLE 3.—Number of Trees, Basal Area per acre, Relative Values and Important Values for the 10 Leading Dominants (4 inches d.b.h. and above) in each of the Three Vegetation Zones.

Species	Mature Upland Forest (14.2 acres)						Second Growth Upland Forest (49.0 acres)						Lowland Forest (6.8 acres)					
	No. Trees	Basal Area	Rel. Den.	Rel. Dom.	IV	IV Rank	No. Trees	Basal Area	Rel. Den.	Rel. Dom.	IV	IV Rank	No. Trees	Basal Area	Rel. Den.	Rel. Dom.	IV	IV Rank
WO	54.4	54.3	47.5	62.6	110.1	1	38.9	27.3	32.1	44.4	76.5	1	3.4	3.4	2.4	5.7	8.1	8
BO	11.8	7.8	10.3	9.0	19.3	2	19.9	10.4	16.4	17.0	33.4	2	....	...	....	....	....	..
PH	11.3	8.0	9.9	9.2	19.1	3	4.3	2.4	3.5	3.9	7.4	7	....	...	....	....	....	..
RO	5.9	4.9	5.2	5.6	10.8	4	5.5	3.7	4.5	6.1	10.6	5	5.3	2.1	3.8	3.6	7.4	9
SH	6.5	1.9	5.7	2.2	7.9	5	10.4	3.0	8.6	4.8	13.4	4	....	...	....	....	....	..
SM	5.6	1.8	4.9	2.1	7.0	6	9.8	4.6	8.1	7.5	15.6	3	23.0	11.8	16.4	20.0	36.4	1
BH	4.0	1.7	3.5	2.0	5.5	7	1.9	.9	1.5	1.4	2.9	10	7.1	2.0	5.0	3.3	8.3	7
MH	2.6	1.3	2.3	1.5	3.8	8	8.0	2.3	6.6	3.7	10.3	6	....	...	....	....	....	..
Be	2.0	1.5	1.7	1.7	3.4	9	....	...	....	....	....	..	....	...	....	....	....	..
SE	2.4	.6	2.1	.7	2.8	10	2.5	0.7	2.1	1.2	3.3	9	11.2	3.5	8.0	5.8	13.8	3
Sa	....	...	....	....	....	..	4.2	0.8	3.5	1.3	4.8	8	7.1	1.2	5.0	2.0	7.0	10
Sy	....	...	....	....	....	..	....	...	....	....	....	..	12.1	7.9	8.6	13.0	21.6	2
BW	....	...	....	....	....	..	....	...	....	....	....	..	8.7	3.5	6.2	5.8	12.0	4
BE	....	...	....	....	....	..	....	...	....	....	....	..	10.5	2.3	7.5	3.8	11.3	5
BB	....	...	....	....	....	..	....	...	....	....	....	..	8.7	1.4	6.2	2.3	8.5	6
Others	8.1	3.0	6.9	3.4	10.3	..	15.7	5.4	13.1	8.7	21.8	..	43.0	20.9	30.9	34.7	65.6	..
TOTALS ..	114.6	86.8	100.0	100.0	200.0	—	121.1	61.5	100.0	100.0	200.0	—	140.1	60.0	100.0	100.0	200.0	—

top ten species had much poorer regeneration and both black walnut and sycamore were not represented in these categories. Numerous shrubs were also found in the lowland forest with bladdernut and wahoo being the most common.

Second Growth Upland Forest.—The area to the east of Rocky Branch Creek is, for the most part, flat to gently rolling upland. It is dissected in several places by intermittent streams that form relatively deep valleys where they enter Rocky Branch or Big Creek. Many of the trees in this area were probably cut after the turn of the century and it still exhibits a disturbed condition at the present time.

As in the mature upland forest, white oak is the dominant species, but here its IV is only 76.5. Rarely does the importance of white oak exceed 100 on the individual quadrats of this zone. Except for quadrats associated with valleys, its IV usually varied from 55 to 90. White oak, together with the second most important species, black oak, make up better than 50 percent of the total IV of this zone. Other important species of this zone are sugar maple, shagbark hickory, red oak and mockernut hickory (Table 3). Though their importance differs, the dominant species of both upland regions is nearly the same. The only difference being that sassafgras replaces beech among the top ten in the second growth upland forest.

Sugar maple is reproducing better than any other woody species in this zone, averaging 2332 seedlings and 27 saplings per acre. Sassafras is also well represented with 714 seedlings and 17 saplings per acre. Among the oaks, white oak has 327 seedlings and 19 saplings per acre while black oak averages 439 seedlings and 15 saplings per acre. Other species with large numbers of seedlings include shagbark hickory, slippery elm and white ash.

The understory trees ironwood, blue beech and flowering dogwood are very common in the second growth upland forest and are well represented in the seedling and sapling categories. The common shrubs include *Rosa carolina* L., *Rubus allegheniensis* Porter, *Ceanothus americanus* L. and *Rhus glabra* L.

The extent of tree mortality is not an important feature of the woods, averaging only 6.5 trees per acre with a basal area of 2.5 square feet per acre. The species with the highest mortality is white oak which averaged 2.1 dead trees per acre with a basal area of 0.7 square feet per acre. Dead slippery and american elms together averaged 1.7 trees per acre with a basal area of 0.9 square feet per acre. These results are similar to those for the western portion of Rocky Branch (Ebinger and Parker, 1969) which averaged 8.6 dead trees per acre with a basal area of 3.0 square feet per acre.

The highest tree mortality occurs in the Rocky Branch Creek lowlands where it averages 10.3 trees per acre with a basal area per acre of 6.1 square feet. This high mortality is due to two species of elm. Slippery elm, with a mortality of 2.9 trees per acre and american elm, with 3.1 trees per acre, comprise 58 percent of the trees and 83 percent of the total basal area. In the mature upland forests mortality averages 8.3 trees per acre and 3.2 square feet of basal area per acre. The major contributors in this zone are white and black oak. Mortality is lowest in the second growth upland zone, averaging 5.1 trees per acre and a basal area of 1.7 square feet per acre. Here white and black oak as well as both species of elm make up the major portion of the dead species.

Coppice trees are not uncommon in the Rocky Branch Nature Preserve. As used here, coppice growth refers to any tree with two or more stems from a common trunk, or only one stem, if it is associated with a stump, or a stem with an extensively swollen butt so as to indicate that it originated as a stump sprout (Downs, 1947). In the more disturbed woods of east-central Illinois coppice growth accounts for over 124 stems per acre and for nearly 50 percent of the stand basal area (Ebinger, 1973). In the Rocky Branch Nature Preserve, however, it averages only 27.7 stems per acre with a basal area per acre of 12.2 square feet (Table 4). White oak, with 6.70 trees per acre and 5.19 square feet, accounts for slightly less than one-half of all the coppice trees and their basal area. The importance of oaks and hickories in the woodlot is again shown, in that out of the first seven species listed as having some regular degree of coppice growth, six of them are either oaks or hickories.

Coppice trees are not very common in the mature forest and in the lowland forest. In the mature forest it averages 5.1 trees per acre with a basal area per acre of 5.3 square feet. White and black oak lead in the number of coppice stems per acre. The lowland forest averages 7.5 coppice trees per acre and a basal area of 5.9 square feet per acre with no one species dominating. The area with the most extensive coppice growth is the second growth forest to the east of Rocky Branch Creek and reflects the more disturbed nature of this zone. Here coppice trees average 19.3 per acre and account for a basal area of 14.5 square feet per acre. White oak is the most important with 8.5 trees and a basal area of 6.6 square feet per acre. It is followed by black oak and sugar maple.

The oaks as a species group are extremely important in the woods. White and black oak have a relatively good size class distribution and many seedlings and saplings. This indicates that these species represent

TABLE 4.—Extent of Coppice Growth

Species	Number of coppice trees per acre	Number of coppice stems per acre	Average number of stems per tree	Basal Area of Coppice Stems per acre	Percent of stems in woods that are coppice
WO	6.70	10.37	1.55	5.19	25.92
BO	2.94	5.67	1.93	2.99	32.56
SM	1.18	1.97	1.66	0.69	18.06
RO	0.87	1.45	1.67	0.77	22.81
SH	0.84	1.51	1.80	0.39	17.01
MH	0.66	1.14	1.74	0.30	18.09
PH	0.30	0.59	1.95	0.23	10.56
Sa	0.30	0.61	2.05	0.12	16.04
BW	0.26	0.57	2.22	0.19	27.97
WA	0.26	0.47	1.83	0.12	27.04
BH	0.23	0.46	2.00	0.16	14.15
Others	1.60	2.93	1.82	1.04	....
TOTALS	16.14	27.74	....	12.19	....

a relatively stable component of the community and their importance in the stand will continue. Red oak has poorer size class distribution and will probably not increase in importance except on more mesic sites.

The hickories as a group are fairly common in the woods. In general, they have good size-class distribution with shagbark and mockernut hickories having better than one half of the individuals in the 4- to 6-inch dimater class and no individuals in the 25-inch or greater class. They rank relatively high in seedlings and saplings and will probably increase slightly in importance in the woods.

Of the more mesic species occurring here, only sugar maple is making any notable advances throughout the woodlot. The number of seedlings (2413 per acre) is greater than the number of seedlings for the two leading species groups (oaks and hickories combined), and the number of saplings (45 per acre) is greater than for any other species. This large number of seedlings and saplings, its good size class distribution, and its ability to take advantage of canopy openings indicates that sugar maple will increase in importance. This indicates an overall trend toward a more mesic woodland situation. This trend has been observed by McClain and Ebinger (1968), Ebinger (1968) and by Ebinger and Parker (1969) in other upland forests in east-central Illinois.

Other species with large numbers of seedlings are white ash, slippery elm and sassafras. The seedlings of white ash have a poor survival value as indicated by the small number of saplings present and it is doubtful that the importance of this species will increase to any extent. Slippery elm, in contrast, ranks ninth in importance and has good size class distribution. The relatively low mortality figures and IV for slippery elm indicates that this species has never been an important component of the stand. The large numbers of seedlings, saplings and small diameter trees now present indicate that it could become much more important. The future of this species in the woods is not known however, because of its susceptibility to Dutch elm disease and phloem necrosis. Sassafras, which ranks tenth in importance in the woods, is well represented in seedlings, saplings and small diameter trees. It is common in the lowland and second growth forests (Table 3) and many seedlings and saplings are found in the mature upland forests. Root, Geis and Boggess (1971) found sassafras to be an important stand component in the upland forest of Hart Memorial Woods in Champaign County, Illinois ,and suggested that its importance is related to the advanced stage of soil development. In the Rocky Branch Nature Preserve, sassafras will initially increase in importance in the second growth upland but will probably decrease as the woods becomes a mature oak-hickory-maple forest.

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INCIDENCE OF CULL IN MANAGED OAK STANDS IN NORTHERN ILLINOIS

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ABSTRACT.—This study describes the technique used at Sinnissippi Forest, in northern Illinois, to obtain cull factors for well-managed upland oak timber. The forest stands are described giving past history and present management policies. Soil types and their relationship to growth and volume are also discussed. A random selection of sample trees was taken, and measurements were made both before and after felling to determine form factors for a local volume table and to determine gross and net volumes. It was found in this study that cull factors based upon the percentage of total cull to calculated gross volume were 6.0, 7.5, and 12.9 percent for white oak on "good," "medium," and "poor" sites, respectively. For black oak the cull percent was 10.8 and 11.5 on "medium" and "poor sites. There is little or no black oak on "good" and "medium" sites was found to have a cull of 7.3 and 11.3 percent, respectively. There is little or no red oak to be found on "poor" sites.

Little information is available on the amount of cull to deduct from standing timber tallies in managed forest stands. Consequently, many service foresters continue to use cull factors developed for unmanaged stands or, assuming that cull is negligible in well-managed stands, use no cull factor at all. Cull can be defined as the volume of material unmerchantable under prevailing utilization practices and is caused by sweep (crook), rot, shake (parting of the annual rings), or other defect.

There is no doubt that proper silvicultural management reduces the amount of cull in residual trees. Gruschow and Trousdell (1959), in a study on rot in unmanaged hardwood sawtimber, developed a grading system based upon standing tree qualities of 1 to 4 and found that 70 percent of the total cull volume was in Grade 4 trees and an additional 20 percent was in Grade 3 trees. Such trees would have been removed first under management. Cooley (1964), working on the effect of selection cutting in northern hardwoods, found that the proportion of unmerchantable material in the poorest residual sawtimber trees had been sharply reduced by one, two, or three selection cuts during the preceding 35 years.

This research was done to determine cull factors that could be used managing the 2,800-acre Sinnissippi Forest, located in Ogle County, Illinois. This privately owned forest has been managed for the past 20 years under the direction of the University of Illinois Department of Forestry.

Stand History and Condition

Sinnissippi Forest, with the exception of its plantations, is predominately 90- to 100-year-old even-aged upland oak timber. White oak (*Quercus alba* L.), black oak (*Q. velutina* Lam.), and red oak (*Q. rubra* L.) account for about 95 percent of the standing timber, while hickory (*Carya ovata* (Mill.) K. Kock and *C. cordiformis* (Wangenh.) K. Kock), elm (*Ulmus americana* L. and *U. rubra* (Mühl.), and cherry (*Prunus seriotina* Ehrh.) make up the remaining 5 percent (Table 1). The site quality of good, medium, and poor represents Mesavage and Girard's (1946) Form Class 79, 78 and 77, respectively, which is the ratio in percent between diameter inside bark at the top of the

first 16-foot log and the diameter outside bark at breast height (4½ feet above ground).

The soils are predominately sandy and were developed under forest or prairie cover. "Good" timber types are usually found in coves or on soils with clay accumulations in the B horizon. "Medium" types may be found on sandy soils with clay lenses in the lower part of the solum.

Indications are that there were no major fires during the development of these stands. Light grazing was carried on in most of the forest until about 1940. Browsing by deer was quite heavy, and in 1957 the forest was opened to hunting on a restricted basis to keep such browsing at a minimum.

Cutting history prior to 1900 is not known, but it appears that most of the older stands were cut for railroad ties and local construction lumber between 1850 and 1860. Between 1900 and 1947, little timber was cut.

The present management system was initiated in 1948 and involves a 10-year cutting cycle on 40-acre compartments. Records for each compartment are kept by timber type, site, and age classification. Growth and mortality records are maintained on 12 permanent sample plots in each compartment. During the first cutting cycle, the forest was systematically covered by improvement cuts in which misshapen, overmature, decadent, or otherwise undesirable trees were harvested or eliminated by girdling. The purpose of this initial cut was to leave the best possible growing stock upon which to concentrate future growth. After the first cutting cycle was completed, improvement cuts were continued using a group selection system and girdling cull trees. One-tenth of the forest was again cut each year, removing the equivalent of 10 years of annual growth, or less if growing stock was low, from each compartment.

The oak wilt disease (*Cerotocystis fagacearum* Bretz) has affected Sinnissippi Forest stands in many scattered areas. Himelick and Fox (1961) reported an average annual loss of 13,866 board feet of merchantable timber from 1945 through 1961 from oak wilt and its control. Control measures have not been completely effective, as some losses are still being suffered.

Present stand composition and volume by species on the upland hardwood sites are shown in Table 1. Annual growth per acre for the 91-110 year age class is 337, 202, and 104 board feet, respectively, for "good," "medium," and "poor" sites; and 162 and 139 board feet for "medium" and 'poor" sites in the 71-90 age class.

FIELD PROCEDURE

The permanent inventory plots were used as reference points to obtain a randomized sample of trees from the upland oak sites. Cull study plots were located 100 feet north of the center stake of the forest inventory plots, provided this point did not fall within 50 feet of a type line change involving species composition, age classification, or site quality change. If a type line was within 50 feet of the proposed location, the location was moved 90 degrees in a clockwise direction until a location was found where no type change was closer than 50 feet. If type line changes interfered with the location in all four cardinal directions, the plot was not used.

After all acceptable plots were separated into site quality classes and randomly sampled, sample trees were selected at each plot location. These were the three nearest red oak, white oak, and black oak trees to the sample point and 11.6 inches

TABLE 1.—Stand composition of upland hardwood sites in board feet per acre

Type	Site	Age class	Board feet, International ¼" log rule						
			White oak	Black oak	Red oak	Elm	Hickory	Misc.	Total volume[1]
Red oak	Good	91-110	816	415	8,576			134	9,941
White oak	Med,	91-110	6,216	725	367		18	9	7,335
White oak	Poor	91-110	3,649	302	202				4,153
Black oak	Poor	91-110	697	2,976	77	10	15	67	3,842
Mixed oak	Good	91-110	3,737	700	5,734	68	34	222	10,495
Mixed oak	Med.	91-110	3,064	2,211	1,177	62	41	214	6,770
Mixed oak	Poor	91-110	1,884	1,926	126			7	3,943
Mixed oak	Med.	71- 90	1,907	1,652	297			42	3,898
Mixed oak	Poor	71- 90	1,046	1,767	107	6	94	12	3,032
Mixed oak	Poor	Uneven	1,759	440		293	60	176	2,728

[1]Gross volume in trees 9.6" or larger in diameter.

DBH or larger. An adequate sample was determined to be 25 trees of each species on each site quality. It appeared unlikely that 25 black oaks on "good" site or 25 red oaks on "poor" site could be found, and no attempt was made to derive cull factors for these categories. As soon as 25 trees of each species were sampled on a given site quality, no additional plots were taken. Only 11 red oaks were found on "medium" sites so the cull factor for this species is based on a smaller number of samples than the established optimum.

Data collected on sample trees, before and after felling, included:

1. DBH and double bark thickness (DBT).
2. Total height.
3. DOB (diameter outside bark) and DBT at stump height.
4. DOB and DBT at 1 foot above stump height.
5. The length, top DOB, and DBT of each log or cull section.
6. DOB and DBT at 16 feet above stump for the Girard form class.

All measurements were coded for future use on IBM cards. The amount of cull in each log was determined using the *National Forest Log Scaling Handbook* (1963).

Logs were sawn at the Sinnissippi Forest mill, and usable lumber was recorded for each log by the following two grades:

1. Shop grade = lumber usable for manufacture into pallets and other items using short unsaleable pieces.
2. Saleable grade = lumber of construction grade or better.

Because of insufficient data for some age classes, all age classes were combined and the following summaries were developed for each species on each of the three site qualities, for all species combined on each of the three site qualities, for all site qualities combined for each species, and for all site qualities and species combined:

1. Gross board-foot volume in the standing tree. Volume in BF = $.0254D^2H - 6.226$, when D = DBH and H = merchantable height (Column 4, Table 2).

TABLE 2.—Total volume in board feet by species and site for 157 sample trees with standard error for critical variables.

Species	Site	No. trees sampled	Volume, International ¼" rule: Standing tree	Gross log scale	Cull	Net log scale	Mill tally
White oak	Good	25	3,839	3,748±14.5	231± 3.4	3,517±14.4	3,772
White oak	Medium	23	3,154	3,081±12.4	238± 3.2	2,843±11.5	3,085
White oak	Poor	25	2,580	2,711±15.6	334± 6.9	2,377±10.9	2,552
Black oak	Medium	23	3,086	2,961±14.2	334± 3.1	2,627±14.8	2,934
Black oak	Poor	25	2,144	2,166± 8.8	246± 2.9	1,920± 8.3	2,111
Red oak	Good	25	7,371	7,508±42.3	542± 4.7	6,966±42.0	7,195
Red oak	Medium	11	3,118	3,151±59.7	352±16.4	2,799±44.8	3,001
Total		157	25,292	25,326	2,277	23,049	24,650

TABLE 3.—Recommended cull factors for managed upland oak timber in northern Illinois.

Species	Site: Good	Medium	Poor	Sites combined
	Percent			
White oak	6.0	7.5	12.9	8.4
Black oak	..	10.8	11.5	11.1
Red oak	7.3	11.3	...	8.5
Species combined	6.9	9.9	12.3	9.0

2. Gross board-foot volume in all sections within the merchantable height whether merchantable or cull (Column 5, Table 2).

3. Net log scale with cull deductions based on the *National Forest Log Scaling Handbook* (Column 7, Table 2).

4. Mill tally in actual board feet sawn (Column 8, Table 2).

RESULTS

Volume and cull data for the 157 sample trees are shown in Table 3. The difference between gross volume and mill tally does not necessarily indicate cull, since this figure constantly changes with utilization standards and milling specifications. The slight overrun on the net log scale indicates good sawing techniques with a minimum of waste in slabs and edgings.

Cull factors based upon the percentage of total cull to calculated gross volumes are shown in Table 3 and are recommended for use in managed upland oak timber in northern Illinois, Iowa, southern Wisconsin, and northern Indiana. These factors should be acceptable for conditions similar to those at Sinnissippi Forest. However, in determining net volumes of standing timber, local volume table, and accurate estimating of merchantable height are of great importance if one is to obtain accurate net volumes.

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FOREST INVASION ON ABANDONED PASTURE LAND AT THE STRONGHOLD IN OGLE COUNTY, ILLINOIS

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ABSTRACT.—A pasture of 34 acres was abandoned in 1948. Several surveys of invasion by woody plants into sample areas were conducted from 1959 through 1972. Twenty-seven species of trees, 20 shrubs and vines, and 78 herbaceous plants were identified. Pioneer invaders were dominated by *Acer negundo*. Other important invaders were *Ulmus americana*, *U. rubra*, *Prunus americana*, and in small areas, *Rhus glabra*. *Quercus velutina* has been an abundant secondary invader. Recently, numerous seedlings of *Fraxinus americana* have appeared. Concentrations of various invading trees have been related to proximity of seed sources, which were mostly fencerows, an abandoned roadway, and adjacent forests. A central gully in a more advanced stage of forest development is also influencing the adjacent parts of the field. It is obvious that in a quarter of a century, abandoned pasture land in a northern Illinois river valley situation can develop into a savanna-like open woods that will gradually progress into a deciduous forest.

The Stronghold, located north of Oregon, Illinois, along the west side of Illinois route 2, consists of about 450 acres of forested hills and valleys. The property is owned by The Presbyterian Camping Association of Northern Illinois and is used for summer camping by youth groups.

Separating the forest into north and south portions is a 34-acre field abandoned as pasture in 1948. This particular site was apparently cleared of its forest shortly after settlement of the area about 1835. It was used for cultivated agriculture until it was badly eroded, with topsoil gone and a deep gully cut through the middle. It was planted in grasses and possibly legumes and used as pasture for livestock for several decades. Since 1948, it has been idle, except for hiking by small groups over established trails. Use and disturbance have been minimal.

The site is located in the center of section 33 of Rockvale Township (T24N., R10E.), Ogle County, Illinois. It is adjacent to Illinois route 2 and extends westward for about 2500 feet (Fig. 1). Its elevation ranges from 700 feet at the east end to 830 feet at the west end. The field is almost entirely sloping, with drainage by old gully channels.

Succession under similar circumstances has been studied and documented for southern Illinois by Voight and Mohlenbrock (1964), Bazzaz (1968), and others. No information on succession is available for other sites in northern Illinois.

Previous papers on the Strong field have reported on competition between forest and prairie vegetation (Bullington, 1970), successional development of the main gully (Bullington, 1971), and a half-century of vegetational development of an old roadway that crosses the east end of the field (Bullington, 1973).

This report, combining data obtained in various surveys from 1959 through 1972, will show the present status of the woody vegetation of the Strong field and will indicate the presence of herbaceous species. This information should be of value in future ecological studies of the field.

Soils The soils of The Stronghold, including the study field, have been typed by technicians of the Ogle County Soil Conservation Service. Additional observations by the author and a soil scientist have veri-

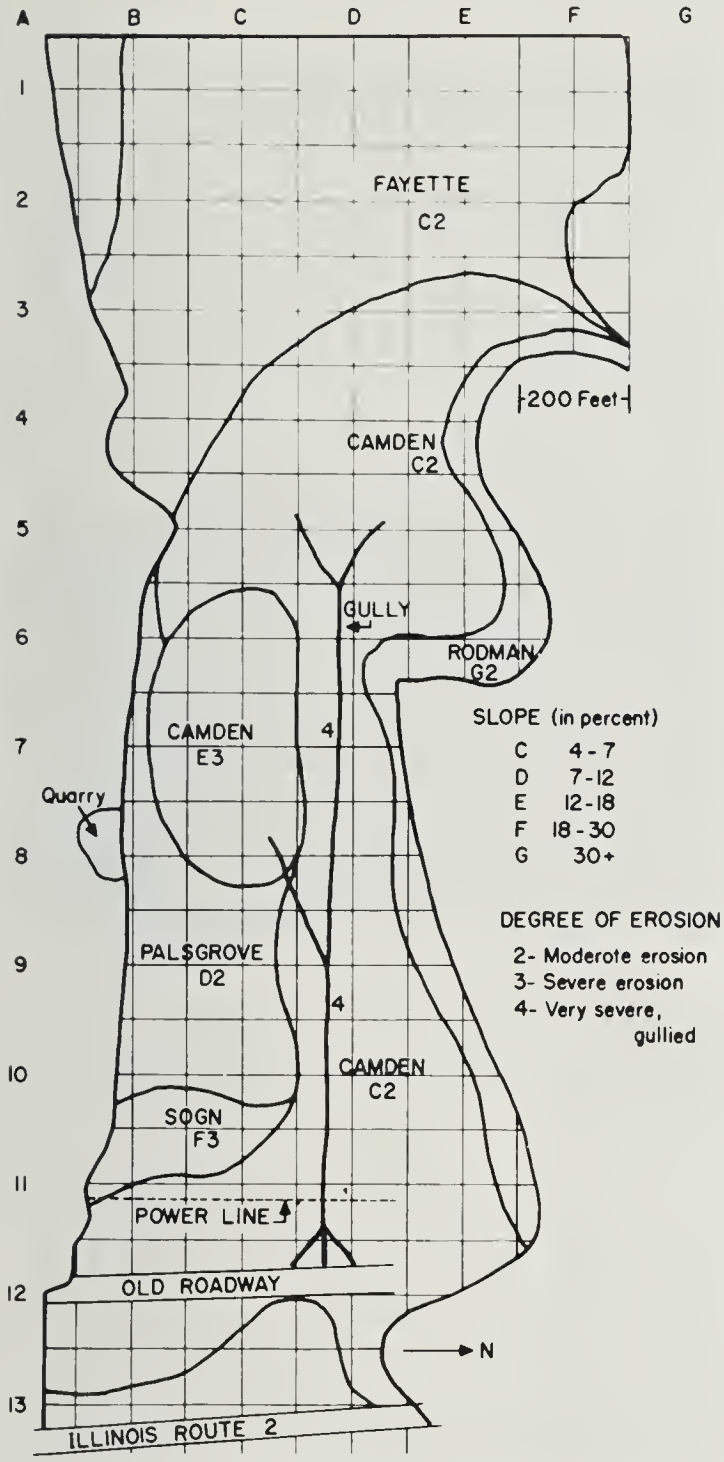

FIGURE 1.—Map of the Strong field at The Stronghold, Oregon, Illinois.

fied the characteristics of the four kinds of silt loam soils identified in the field. Figure 1 gives the locations of the kinds of soil. Letters with the names indicate the percent of slope, and numbers, the degree of erosion. (See explanation with Figure 1).

The largest portions of the field are covered with Camden silt loam and Fayette silt loam. Camden is found at lower elevations and has developed in silt deposits, some sandy and others of clay. Fayette silt loam covers the western portion of the field which is the most level. It developed in a loess deposit. Much of the east part of the field has Palsgrove silt loam over sandy limestone. Crumbling rocks are found very near the surface. Only this part of the field has an alkaline pH, and it is here that the principal development of sweet clovers (*Melilotus*) and hop tree (*Ptelea trifoliata*) occur.

At the east end and south edge are small areas of Sogn silt loam, developed on steeper slopes over limestone. This type is present in the entire strip of adjacent forest on the south side. An old limestone quarry is present at the midpoint of this forest edge. It was opened on the north slope of a steep valley.

The adjacent forest on the north has Rodman gravelly loam, a loose soil with a small amount of loam over calcareous gravel. It drains rapidly. This fact may be the chief reason for the dominance of black oak (*Quercus velutina*) in much of this forest, for this species is usually dominant on relatively xeric sites of sand or gravel in northern Illinois.

All of these soils are types that developed under deciduous forest. They tend to be well drained, with good permeability of air and water, but they are subject to erosion. Their best use, recommended by the SCS, is pasture, woodland, or wildlife area. Agriculture should be limited to the more level portions. The first settlers made a mistake in clearing the original forest and cultivating the soil of this site. The result was eventual loss of topsoil and formation of gullies, which in turn led to use as pasture.

Bard (1952) reported very little change of Piedmont soils after 60 years of succession. To date the Strong field shows little evidence of topsoil restoration. Neglible amounts of humus have been incorporated into the upper layer of soil.

METHODS

The first observations in the Strong field were made in 1958, ten years after cessation of use as pasture. In 1959, six permanent quadrats of 4x25 m. were established along the north side (Fig. 1, D, 6-11). All plants in each were recorded. A report of this and other early observations have been published (Bullington, 1970).

More recent surveys include a quarter-method study of 18 points at 100-feet intervals through the middle of the field in 1967. This was followed in 1970 by a study of 18 quadrats of 10x10 m. randomly selected along or near the same transect. (Fig. 1, C, 1-11). Figure 2 shows a typical area sampled in these surveys.

In order to check on seed sources from the adjacent forests, a survey was made in 1969 of all trees in 50-feet strips of forest border at both the north and south margains of the east half of the field. The north forest strip was approximately 1000 feet long (Fig. 1, E6-F11), and the south was 600 feet long (Fig. 1, B8-B11). Figure 3 shows the east end of the field with the northern forest in the background.

FIGURE 2.—Twenty years of development of mixed species of trees in abandoned bluegrass pasture.

FIGURE 3.—East end of Strong field looking north, showing tree invasion in abandoned pasture, with oak forest in background.

In 1970 a repeat study of the tree population was made in the six permanent quadrats. Also in that year, the largest tree of each common species in the field was sought and measured.

A final search for new herbaceous species and for tree seedlings was made by reconnaissance in various parts of the field in 1972.

Data concerning relative frequency, relative density, relative dominance, and importance values (IV) were determined according to Curtis and Cottam, 1962. A modification was made in the determination of relative dominance. Diameter readings (dbh) at 4½ feet were made on all trees over six feet in

height in the various surveys. Because of the small diameters of many trees, basal areas were not determined. Therefore, diameters rather than basal areas were used in figuring relative dominance.

The botanical nomenclature follows that used by Fernald (1950). All identifications were checked in both Fell (1955) and Swink (1969) for confirmation of their likely presence in northern Illinois.

RESULTS

Twenty-seven species of trees have been identified in the Strong field. Table 1 lists them with their rank order of abundance indicated from various surveys. Symbols assigned to each species in Table 1 are used in other tables.

TABLE 1.—Summary of trees of Strong field with rank order of abundance for various locations.

	Sample Area		Gully	S. Field	N. Field	N. Forest	S. Forest	Field Seedlings
	Method		Survey	Quad.	Quad.	Survey	Survey	Recon.
	Year		1969	1970	1970	1969	1969	1972
Scientific Name	Common Name	Symbol						
Acer negundo L.	box-elder	BE	5	1	5	F	9	F
Acer saccharum Marsh.	sugar maple	SM	F					F
Betula papyrifera Marsh.	white birch	WB					F	
Carya cordiformis K. Koch	bitternut hickory	BHi						F
Carya ovata K. Koch	shagbark hickory	SH	7		6	1	4	F
Catalpa sp.	catalpa	Ca	F					
Celtis occidentalis L.	hackberry	H	3	F	10	5	6	F
Crataegus crus-galli L.	cockspur-thorn	CT		8				
Crataegus mollis Scheele	red haw	RH	12	6	8			
Fraxinus americana L.	white ash	WA	13	F			2	1
Gleditsia triacanthos L.	honey locust	HL						F
Juglans nigra L.	black walnut	BW	2	7	1	F	3	F
Juniperus virginiana L.	red cedar	RC	11	F		F	F	F
Populus grandidentata Michx.	large-toothed aspen	A	9		7	6		6
Prunus americana Marsh.	wild plum	P	F	A				
Prunus serotina Ehrh.	black cherry	BC	6	5	11	7	5	3
Ptelea trifoliata L.	hop tree	HT	F					F
Pyrus ioensis Bailey	wild crab	WC	10	2	4			4
Quercus alba L.	white oak	WO	F			4	F	5
Quercus macrocarpa Michx.	bur oak	BO	F					
Quercus rubra L.	red oak	RO			F			
Quercus velutina Lam.	black oak	B10	4	9	2	2	7	2
Tilia americana L.	basswood	B						F
Ulmus americana L.	American elm	AE	8	3	9		8	
Ulmus pumila L.	Siberian elm	SE						F
Ulmus rubra Muhl.	red elm	RE	1	4	2	3	1	
Viburnum prunifolium L.	black haw	BHa	F					

Key: A = Abundant, but not included in rank
F = Few, less than five specimens

TABLE 2.—Quarter method survey: Tree population of 18 points at 100-feet intervals along an east-west transect (July 1967).*

Species in Order of Importance	No. Points of Occurrence	Total No. Trees	Rel. Frequency	Rel. Density	Rel. Dominance	Importance Value
BE	15	32	32.6	44.4	27.8	104.8
AE	4	5	8.7	6.9	33.8	49.4
RE	6	9	13.0	12.5	8.4	33.9
RH	6	9	13.0	12.5	5.1	30.6
P	5	5	10.9	6.9	4.7	22.5
SE	3	5	6.5	6.9	7.8	21.2
BC	3	3	6.5	4.2	5.4	16.1
WC	3	3	6.5	4.2	2.6	13.3
BW	1	1	2.2	1.4	4.3	7.9
Totals	46	72				

* Symbols of species are from Table 1.

The results of quarter and quadrat surveys along a transect through the middle of the field are shown in Tables 2, 3, and 4. The IV's of the tree species have been determined. In the quadrat survey of 1970, the wild plum (*Prunus americana*) and hop tree were included with the shrubs, etc., of Table 4.

The quarter survey of 1967 (Table 2) showed only nine tree species including wild plum. The box-elder (*Acer negundo*) was much more important than other species. The american elm (*Ulmus americana*), red elm (*U. rubra*), and red haw (*Crataegus mollis*) were next in order.

TABLE 3.—Quadrat survey: Tree population in 18 quadrats located at random along an east-west transect (Oct. 1970).

Species in Order of Importance	Presence Number Quadrats	Total No. Trees	Trees Over 6 ft.	Rel. Frequency	Rel. Density	Rel. Dominance	Importance Value
BE	16	272	152	17.4	42.9	30.6	90.9
WC	16	147	76	17.4	23.2	10.5	51.1
AE	10	68	67	10.9	10.7	20.9	42.5
RE	15	55	53	16.3	8.7	17.5	42.5
BC	14	43	34	15.2	6.8	10.5	32.5
RH	5	19	19	5.4	3.0	3.5	11.9
BW	5	13	12	5.4	2.0	4.3	11.7
B10	5	5	3	5.4	0.8	0.7	6.9
CT	2	6	4	2.2	1.0	0.5	3.7
H	2	2	2	2.2	0.3	0.6	3.1
RC	1	2	1	1.1	0.3	0.4	1.8
WA	1	2	1	1.1	0.3	0.0	1.4
Totals	92	634	424				

TABLE 4.—Presence of shrubs, vines and small trees in 18 quadrats (Oct. 1970).

	Number of Quadrats				
	Of East 9	Of West 9	Total	Percent Of 18	Total Specimens
Species					
Prunus americana	8	7	15	83.3	256
Ptelea trifoliata	5	1	6	33.3	8
Rhus glabra	2	1	3	16.8	102
Rhus radicans		3	3	16.8	many
Ribes missouriense		1	1	5.5	2
Sambucus canadense		1	1	5.5	3
Smilax tamnoides		1	1	5.5	1
Vitis riparia	1	4	5	27.8	30

The quadrat survey of 1970 (Table 3) revealed more species of trees, a total of 12, probably because of the larger sampling by this procedure. There were 634 trees compared to 72 in the 1967 quarter-method study. Box-elder was again the most important. Wild crab (*Pyrus ioensis*) was second, with the elms next with equal IV. It should be noted that some dead American elms were not counted. Black cherry (*Prunus serotina*) was fifth in IV.

The location of the transect for these two surveys was chosen because of its mid-position in the east-west axis of the field. It was the most remote from influence by adjacent forests and gully. This central strip had the least dense tree population of the field. The seeds of all invaders, with the exception of walnut and oak, were probably introduced by either wind or birds. In general, the more abundant tree species were wind disseminated. The second survey showed no evidence of invasion of new species following the study of three years earlier. Nearly all trees had been established during the early days after abandonment of the pasture, or possibly before. At present, the central portions of the field are stabilized in the pioneer stage of forest succession with 1426 trees per acre plus an additional 993 shrubs, vines, and small trees, the latter including plum and hop tree.

The six permanent quadrats at the north side of the field contained 11 species of trees in 1959 and only one additional, a single specimen of white oak (*Quercus alba*), in 1969 (Table 5). Black walnut (*Juglans nigra*), black oak, and red elm had the greatest abundance and also the greatest IV in 1970. All had increased in numbers since 1959. Only the box-elder was more common than these three in 1959. It decreased from first rank in 1959 to fourth, with a decrease in specimens from 64 to 28. Many had died, apparently from shading. The decline of this pioneer invader has been noted for the more open center of the field. In the central gully, it was found that one half of the box-elder trees were dead in 1969 (Bullington, 1971).

Wild crab and large-tooth aspen (*Populus grandidentata*) made significant increases in numbers and in rank. Several other species declined by a few specimens each.

In a period of 11 years there was no significant change in overall numbers and little change in species composition, but there was a decided increase in growth. The number of

TABLE 5.—Tree population in six permanent quadrats at north side of field (Nov. 1970).

Species in Order of Importance	No. in 1959	Presence Number Quadrats	Total No. Trees	Trees Over 6 ft.	Rel. Frequency	Rel. Density	Rel. Dominance	Importance Value
BW	55	6	59	45	16.2	18.8	22.3	57.3
B10	47	4	56	34	10.8	17.9	26.5	55.2
RE	41	4	56	34	10.8	17.9	14.0	42.7
WC	23	5	41	20	13.5	13.1	6.5	33.1
BE	64	3	28	22	8.1	9.0	11.0	28.1
AE	14	3	10	7	8.1	3.2	6.6	17.9
A	5	2	17	14	5.4	5.4	5.7	16.5
RH	18	3	13	5	8.1	4.2	1.9	14.2
BC	8	3	5	5	8.1	1.6	4.3	14.0
SH	25	2	21	5	5.4	6.7	1.1	13.2
H	4	1	6	1	2.7	1.9	0.1	4.7
WO	0	1	1	0	2.7	0.3	0.0	3.0
Totals	304	37	313	192				

trees over six feet in height increased from 30 to 192. The total number of trees per acre was 2,112 in 1970, much greater than the concentration through the middle of the field.

The results of the survey of adjacent forest strips are shown in Table 6. The data show 10 species of trees in the north forest strip and 12 in the south strip. The northern forest is a xerophytic association with black oak and shagbark hickory (*Carya ovata*) dominant. There is considerable recent reproduction of the latter. Red elm is the most common understory tree.

TABLE 6.—Tree populations in 50-feet-wide strip of adjacent forest edge (Nov. 1969).

	North Side of Field (1000-Feet Strip)						South Side of Field (600-Feet Strip)					
Size Classes in inches dbh	-1	1-6	6-9	9-12	12+	Total	-1	1-6	6-9	9-12	12+	Total
Species												
BE	1					1		5	2			7
WB											3	3
SH		141	15	7	6	169		12	10	7	5	34
H	4	3	2		2	11		15	1		2	18
WA								38	7	3		48
BW		1	1		2	4		9	21	7	6	43
RC	4					4	1					1
A		1	1	6	1	9						
BC		1	2	1	2	6		21	8	3		32
WO		3	2		7	12				1	1	2
B10	1	9	12	7	22	51		5		3	6	14
AE								1	7	2		10
RE	4	18	3	2		27	many	many	2		2	many
Totals	14	177	38	23	42	294	1+	106+	58	26	25	216+

The greater diversity of species in the south forest strip reflects a less xeric environment. There is no clear dominance among 10 species of canopy trees, although shagbark hickory, black walnut, and black oak outnumber the others among the larger trees. It is worthy of note that no sugar maple (*Acer saccharum*) or basswood (*Tilia americana*) were found in the south strip, even though they are abundant in a mesic valley a few hundred feet to the south. However, a few seedlings and saplings of each are now present in the southern portion of the Strong field.

Special mention should be made of the presence of three white birch (*Betula papyrifera*), all over 12 inches dbh, and a few additional dead ones at the edge of an old limestone quarry. Their presence is unusual in a dry-mesic forest environment in northern Illinois, but they are probably relics. They have been reproducing, for several vigorous saplings are growing in the south part of the field. These do not appear in the statistics of any of the study areas.

Table 7 shows the counts of tree seedlings observed in 50-feet-wide corridors by two persons walking in the areas indicated in the headings. The locations were chosen because they were near good seed sources and seemed to have the most new trees of all locations in the field.

White ash (*Fraxinus americana*) showed the most active reproduction, especially along the south side of the field adjacent to good seed sources. Black oak was second in abundance overall, prominent in all sample areas and the most common seedling near the gully. Black cherry was next in abundance and of first importance at the north edge.

Measurements of dbh of the largest trees of each species revealed a black cherry of 9.2 inches, a black oak of 8.6 inches, and a red elm of 8.5 inches. There was an American elm of 7.6 inches, but larger ones had died. Two other species had

TABLE 7.—Numbers of tree seedlings in selected areas, by reconnaissance survey (Oct. 1972).

Species	North Edge Near Forest	South Edge of Gully	South Edge Near Forest	Totals
BE	3	1		4
SM			1	1
BHi			1	1
SH		1	2	3
H		1	3	4
WA	11	5	many	many
HL			1	1
BW	1			1
RC			2	2
WC	7		4	11
A	2	4		6
BC	23	4	3	30
HT	1	2		3
WO	5		3	8
B10	12	25	17	54
L			1	1

specimens over 5 inches, red cedar (*Juniperus virginiana*) at 5.7 and black walnut at 5.5. Among recent invaders, white ash was represented by a tree of 4.7 inches and sugar maple by one of 1.7.

Box-elder, although abundant and the dominant pioneer of the field, had no representative over 4.4 inches. However, in gully and roadside areas, there are large specimens of this species. In the field, there is a strong tendency for this tree to die in its second decade, leaving numerous short-lived basal sprouts.

DISCUSSION

Secondary succession has not been studied extensively in the midwestern states, in part because suitable sites of abandoned lands are not as common as in the New England and other east coast states. Of those studies in the midwest reported in the literature, few are concerned with former pastures or hay meadows.

Beckwith (1954), Weigert and Evans (1964), and Brewer, Reim, and Robins (1969) all reported on forest invasion into grass-dominated fields. Watts (1957) told an interesting story of the role of piles of cow dung as centers of invasion by hawthorns in a pasture of northern Illinois.

The Strong field appears to have been invaded by woody species very rapidly after cessation of pasturing in 1948. There may have been many small barren spots on which plants could develop. Within the past decade, there has been little change in species composition. During this period the soil has had a complete cover of grasses and forbs, even under well-developed trees, so there has been little space for new invaders. It is possible that woody plants were present prior to 1948, but in a suppressed condition because of grazing.

The study of Weigert and Evans in southeastern Michigan showed that areas dominated by various grasses remained in the grass-forb stage for 30 years. They predicted eventual oak-hickory forest, however. Levy (1970) reporting on upland openings in northern Wisconsin, stated that grass sod can reduce tree success by its mere physical presence.

Beckwith (1954) observed that succession was retarded in hay fields, for at the time of abandonment they had a heavy growth of perennials. He did not encounter an intolerant tree stage. This contrasts with the Strong field, where early invasion was largely by shade-intolerant tree species.

It should be noted that the more level portions of the west half of the field may have been used for cutting hay at one time. An aerial photo of 1939 by the U.S. Department of Agriculture shows patterns that were probably made by mowing and removing the grassy cover. A later photo of 1951 reveals no evidence of mowing.

Beckwith also emphasized the influence of brushy fencerows in promoting invasion, which tends to gradually spread from the periphery to the center of the field. Brewer *et al* noted two kinds of invasion, extension from the borders and scattered invasion promoted by wind and birds. He stated that density per acre was related to distance from source. Bard (1952) indicated that the smaller the field and the closer the woodlot, the sooner the invasion.

In the Strong field there is a fairly even distribution of wind-disseminated woody species (box-elder and elms) with a heavier concentration of mammal- and bird-carried species near the margins. This is especially true of the oaks and hickories which are concentrated near their seed sources. The black walnut is rather

widely distributed, spreading from both adjacent forests and central gully, probably with the help of squirrels.

Vegetative spread from the center of clones is common in many spots. Large-toothed aspen (*Populus grandidentata*) is enlarging its territory from two clones along an old fence of the north border and from scattered specimens in the gully. Especially noticeable are the clumps of smooth sumac (*Rhus glabra*) in several locations, steadily extending their coverage through the years. The dense shade under the older stems in the center of the clones tends to eliminate the grasses and forbs. Some trees, such as black walnut and black cherry, enter the area and eventually overgrow the sumac which then dies. Some of the older sumac stems were dying by 1970.

The hop tree (*Ptelea trifoliata*) is present mainly on the eastern slopes of the field where limestone is close to the surface. It is showing little reproduction. Cockspur thorn (*Crataegus crus-galli*) is scattered over the same area. It is not reproducing and is not present elsewhere in the vicinity, either in the field or adjacent to it.

Poison ivy (*Rhus radicans*) has been spreading rapidly in partially shaded areas. The dense ground-covering clones tend to have stems of even height because of the browsing by deer above winter snow cover. Extensive cropping of black oak and hackberry (*Celtis occidentalis*) seedlings has been noted along the north margin of the field. Winter girdling of small hackberry by rabbits has been observed after deep snow. It is apparent that various animals have an influence on both the spread and suppression of some woody species.

Except for grape (*Vitis riparia*) and poison ivy, common forest vines and shrubs are relatively scarce, even though a total of 20 species has been identified. They are listed in Appendix I.

Root, Geis, and Boggess (1971) reported that sassafras (*Sassafras albidum*) and persimmon (*Diospyros virginiana*) are usually the first woody plants to appear in fields abandoned from cultivation in southern Illinois. These species are not present in northern Illinois. The dominant pioneer woody species in Strong field have been box-elder, American and red elm, wild plum, smooth sumac in small areas, and to a lesser extent black cherry, wild crab, and red haw. The pioneer box-elder and American elm are now dying.

The role of the wild plum is puzzling. It is scattered throughout the middle of the field (Table 4) and dominant in dense thickets in the western half of the field in places that were apparently mowed for hay. The plum thickets are mostly less than six feet high, over a ground cover of bluegrass and with no other trees except stunted box-elders. To date there is no evidence of replacement of the plums.

After 25 years of successional development following several decades of grazing, the Strong field has the general appearance of a savanna of young trees in a setting of grasses and forbs, with local concentrations of shrubs, vines, or small trees. Only in the portion between the gully and the north forest (Fig. 1, D, 6-11) is there a definite development of forest. However, the rapid growth of a forest type in both the gully (Bullington, 1971) and the abandoned roadway (Bullington, 1973) at the east end point to an eventual restoration of a deciduous forest in the field. The recent invasion of numerous white ash along the south side of the field shows a trend toward more advanced forest development.

Black oak is likely to become an important component of the field vegetation in the future. It is second in abundance in the north quadrats, as it is in the adjacent forest, and is second among the seedlings. Many fine specimens are well established throughout the field. Whitford and Whitford (1971) found that in Wisconsin the black oak grew three times faster in an old field than in a forest, with a much better survival rate. Observations indicate similar development in Strong field. The well-drained soil is conducive to further black oak development and eventual dominance.

Although the first decade of successional development in the Strong field was not observed, the early stages of invasion in an abandoned bluegrass lawn nearby (Fig. 1, AB, 12-13) have been closely watched. Within one year of the cessation of mowing, the lawn was populated by 19 species of grasses and herbs, most of which are considered weeds. No doubt many were there in suppressed condition during the years of mowing. An additional eight species appeared in the second season. Almost one half of the total were native species of open places; the remainder were introduced plants.

Seedlings of three species of trees appeared the first season, three more the second, and one more the third. Within five years the lawn had become a dense thicket dominated by box-elder, three species of elms, and black cherry. Good seed sources of all were adjacent to the area. This development in the lawn apparently closely duplicates what happened in most of the Strong field.

To date 78 kinds of herbaceous plants have been identified in the Strong field (Appendix II). Each year new ones are discovered. The list to date is not a complete inventory. Undoubtedly there are species of grasses, sedges, asters, and others not yet identified.

Diversity among the herbs is increasing. In the earlier years, farm weeds and cultivated grasses and legumes were abundant. Many of these are gradually being replaced in the openings by typical plants of openings such as asters and goldenrods and, under the trees, by an increasing number of forest types.

Still persisting, even in the shade, is Kentucky bluegrass (*Poa pratensis*) which tends to keep the soil covered, excluding most invaders and preventing erosion.

Caruso (1970) has reported that the biennial sweet clovers (*Melilotus alba* and *officinalis*) tended to occur in patches scattered throughout a carpet of blue grass and to spread out from the area of origin by heavy seed crops. This situation exists in the Strong field where there are large patches of the sweet clovers. Their dense growth eliminates most other plants but helps to improve the soil.

A few unexpected plants have been found, but in special habitats or fringe areas. Great blue lobelia (*Lobelia siphilitica*) has appeared in the low ground near the east end of the gully and showy orchis (*Orchis spectabilis*) is moving into the field from the gully. Ebony spleenwort (*Asplenium platyneuron*) has been tentatively identified at the gully margin. As previously reported (Bullington, 1971), the gully is in a much more advanced stage of forest development and is now populated by numerous forest species.

Special note should be made of the presence of almost an acre stand of Indian grass (*Sorghastrum nutans*) in a small valley along the north margin (Fig. 1, E, 5-6). Since 1959 the density of the stand has increased considerably, but so also has peripheral encroachment by

large-tooth aspen. On at least two ossacions, in 1968 and 1971, aspen and other woody invaders have been removed by cutting and pulling. This has not effectively controlled the aspen. Very few other herbaceous species are present in this Indian grass stand.

CONCLUSIONS

The quarter century since 1948 has b r o u g h t definite and rapid changes to the character of the Strong field. It has progressed from open pasture to a savanna-like field with scattered trees and, in part, to a young forest of considerable variety. Such development has not been recorded for any other site in northern Illinois.

Numerous authors have discussed the values of studies of secondary succession. V o i g h t and Mohlenbrock have given an excellent summary of this subject on pages 60-61. Also they have proposed a probable secondary succession sequence for southern Illinois.

There is insufficient information to make a complete proposal for a sequence in northern Illinois, much of which was originally prairie. Near river valleys there is an invasion by pioneer woody species on abandoned land and a trend toward ultimate development of a deciduous forest. It is obvious that local edaphic and physiographic factors as well as seed sources are important in determining the course of development.

The Strong field of this study offers a unique opportunity for future ecological studies of both floral and faunal development as well as soil and microclimatic changes. The management of The Stronghold, The Presbyterian Camping Association of Northern Illinois, is very cooperative and interested in preserving the area from excessive disturbance.

Many avenues of investigation are open because of the great diversity in the field and environs, from mature adjacent forests through gully, abandoned roadway and fencerows to grassy openings among the pioneer trees.

It is hoped that this paper and previous reports by the author are but the beginning of long and intensive studies of the Strong field.

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APPENDIX I

SHRUBS AND VINES

Amelanchier sp.—Juneberry
Berberis Thunbergii DC.—Japanese barberry
Celastrus scandens L.—climbing bittersweet
Cornus racemosa Lam.—gray dogwood
Corylus americana Walt.—hazelnut
Lonicera sp.—ornamental honeysuckle
Parthenocissus quinquefolia Planch.—Virginia creeper
Rhus glabra L.—smooth sumac
Rhus radicans L.—poison ivy
Ribes missouriense Nutt.—Missouri gooseberry
Rosa arkansana Porter var. *suffulta* Cockerell—prairie rose
Rosa multiflora Thunb.—multiflora rose
Rubus allegheniensis Porter—blackberry
Rubus flagellaris Willd.—creeping blackberry
Rubus occidentalis L.—black raspberry
Sambucus canadensis L.—common elderberry
Smilax tamnoides L. *hispida* (Muhl.) Fern—bristly green brier
Viburnum prunifolium L.—black haw
Viburnum trilobum Marsh.—highbush cranberry
Vitis riparia Michx—riverbank grape

APPENDIX II

HERBACEOUS PLANTS

Abutilon theophrasti Medic.—velvet-leaf
Achillea millefolium L.—common yarrow
Ambrosia artemisiifolia L.—common ragweed
Ambrosia trifida L.—great ragweed
Amorpha canescens Pursh—leadplant
Amphicarpa bracteata Fern.—hog-peanut
Andropogon scoparius Michx.—little blue-stem grass
Anemone cylindrica Gray—thimbleweed
Antennaria neglecta Greene—pussy's toes
Apocynum androsaemifolium L.—spreading dogbane
Aquilegia canadensis L.—wild columbine
Asclepias sullivantii Engelm.—milkweed
Asclepias verticillata L.—whorled milkweed
Asparagus officinalis L.—asparagus
Asplenium platyneuron (L). Oakes (?)—ebony spleenwort
Aster azureus Lindl.—sky-blue aster
Aster laevis L.—smooth blue aster
Aster pilosus Willd.—hairy aster
Aster sagittifolius drummondii (Lindl). Shinners—Drummond's aster
Bouteloua curtipendula Michx.—tall grama-grass
Campanula americana L.—tall bellflower
Carex sp.—sedge

APPENDIX II Continued

Cirsium arvense Scop.—Canada thistle
Cirsium vulgare Tenore—common or bull thistle
Convolvulus arvensis L.—field-bindweed
Desmodium illinoense Gray—tick-trefoil
Dianthus armeria L.—Deptford pink
Erigeron annuus Pers.—daisy fleabane
Eupatorium rugosum Houtt.—white snakeroot
Euporbia corollata L.—flowering spurge
Galium circaezans Michx.—wild licorice
Gentiana flavida Gray—yellowish gentian
Gnaphalium obtusifolium L.—everlasting
Helianthus sp.—sunflower
Hypericum perforatum L.—St. John's-wort
Lactuca sp.—wild lettuce
Lespedeza capitata Michx.—round-headed bush clover
Liparis lilifolia Richard—broad-leaved twayblade
Lobelia siphilitica L.—great blue lobelia
Medicago lupulina L.—black medick
Melilotus alba Desr.—white sweet clover
Melilotus officinalis Lam.—yellow sweet clover
Monarda fistulosa L.—wild bergamot
Orchis spectabilis L.—showy orchis
Oxalis stricta L.—yellow wood sorrel
Panicum sp.—panic grass
Pastinaca sativa L.—parsnip
Penstemum hirsutus (L.) Willd.—beard tongue
Petalostemum perpureum (Vent.) Rybd.—prairie clover
Phleum pratense L.—timothy
Physalis heterophylla Nees—clammy ground cherry
Physalis subglabrata Mackenz. and Bush—tall ground cherry
Plantago major L.—common plantain
Poa pratensis L.—Kentucky bluegrass
Portulaca oleracea L.—common purslane
Potentilla arguta Pursh—tall cinquefoil
Prunella vulgaris lanceolata (Bart.) Fern.—self heal
Rudbeckia hirta L.—black-eyed Susan
Rumex acetosella L.—sheep sorrel
Rumex altissimus Wood—pale dock
Rumex crispus L.—curly dock
Sanicula gregaria Bickn.—black snakeroot
Setaria glauca Beauv.—yellow foxtail
Sisyrinchium albidum Raf.—common blue-eyed grass
Solanum carolinense L.—horse-nettle
Solidago altissima L.—tall goldenrod
Sorghastrum nutans Nash—Indian grass
Specularia perfoliata (L.) A. DC—Venus's looking-glass
Taraxacum officinale Weber—common dandelion
Tucrium canadense L.—wood sage
Tradescantia ohiensis Raf.—spiderwort
Tragopogon pratensis L.—goat's-beard
Trifolium pratense L.—red clover
Trifolium repens L.—white clover
Triosteum perfoliatum L.—late horse gentian
Verbascum thapsus L.—common mullein
Verbena stricta Vent.—hoary vervain
Verbena urticifolia L.—white vervain

EFFECTS OF GROUND FIRE ON SPRING WILDFLOWER POPULATIONS OF OAK-HICKORY FORESTS

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ABSTRACT.—Two forested areas, located in East-Central Illinois and West-Central Indiana, sustained ground fire in the spring and fall of 1971, respectively. The spring herbaceous stratum was sampled by 32 square meter plots in the burned and unburned sections of each study site. Significant changes in density were recorded for 8 of 11 wildflower species in the spring-burned tract; 8 of 10 wildflower species had significant density differences due to fall burning. Frequency changes were significant for 7 and 6 species, respectively. Species characteristic of undisturbed forest conditions decreased substantially in density and frequency; whereas, species commonly found on disturbance forest sites increased markedly.

The role of fire as a modifier of forest composition and succession patterns has been documented by numerous workers (Lemon 1949; Buell and Cantlon 1953; Hodgkins 1958; Ahlgren 1960; Cooper 1960). The voluminous forest fire literature was reviewed by Ahlgren and Ahlgren (1960), and Cushwa (1968) summarized more than 800 bibliographic entries concerning fire for a 40-year period. Despite this considerable interest in fire ecology, and although deliberate or inadvertent burning of eastern deciduous forests occurs frequently, few studies have dealt specifically with the effects of ground fires on spring wildflower populations of hardwood forest communities.

Fortuitous burning of two areas in west-central Indiana and adjacent Illinois provided the basis for this study. A portion of one forested tract in Clark County, Illinois, was burned by light ground fire on April 11, 1971. Similar burning occurred in Vigo County, Indiana, in late October of the same year. Neither area had any evidence of previous burning in the recent past. Since both sites were similar, had similar forest cover and were located only 8½ airline miles apart, the major variable was time of burning.

The aims of this study were as follows: 1) To examine the effects of ground fire on the density, frequency and diversity of spring wildflower populations occurring in adjacent burned and unburned areas; 2) To determine if the effects of spring burning after most species had vernalized was more serious than fall burning when herbaceous species were dormant.

Study Sites

The Vigo County, Indiana, site contains about 15 acres of upland oak - hickory dominated hardwood forest that has sustained only minor disturbance during the past 30 to 40 years. Young trees (to 24" diameter) create a nearly-closed canopy. The stand is located adjacent to the Village of St. Mary's of the Woods in the N½, SW¼, Sect. 1, Twp. 12 N, Range 10 W. The study section occupies a northeast-facing slope of 47%.

About ½ acre of the area was burned by light ground fire in late October, 1971. Apparently a roadside debris fire escaped and burned into the woods before it was extinguished naturally. Although moderately moist conditions prevailed, all leaf litter was burned and some shrubs and tree reproduction were

killed. The only variable of consequence between the burned and unburned sections was burning, as vegetative cover, topography, soils and other environmental conditions were similar.

The Clark County, Illinois, site contains about 80 acres of oak-hickory forest that has sustained no cutting or grazing for at least 30 years. Canopy trees (to 32" diameter) provide closed canopy conditions. The stand is located 1¼ miles southwest of the village of Dennison in the W½, SW¼, Sect. 35, Twp. 12 N, Range 11 W. The study site occupies a southwest-facing slope of 7%. There were no apparent environmental differences between the burned and unburned sections.

About 2 acres were burned by ground fire that escaped from a burning fence row on April 11, 1971. All woody stems under 2 inches diameter and all above-ground portions of vernalized spring wildflowers were killed. No fire-caused mortality of mature trees was noted. The Dennison fire, which was fanned by spring winds, burned at higher temperatures than did the St. Mary's burn. Ground fuels were extremely dry due to the absence of spring rains for over 3 weeks. All leaf litter and smaller dead limbs were completely consumed by the fire.

METHODS

Thirty-two sample plots were laid out in each of the burned and unburned portions of each study site in early March, 1972. Plots were systematically located 1 meter apart along transects that ran normal to the slope axis. Rectangular plots ½ m x 2 m were used to facilitate tallying from the plot perimeter.

Full counts of all identifiable spring herbs were taken in each plot. Tallies were taken on April 11 and May 2 at the St. Mary's, Indiana, site, and on April 14 and May 6 at the Dennison, Illinois, location.

Species attributes of total density, relative density, and frequency were calculated separately for the burned and unburned sections of each study location for each sampling time. Computations were based on the 32 plots considered collectively as separate communities or "stands." Diversity indices were computed for each of the four areas according to Simpson's (1949) formula.

Differences in density and frequency values for each species and for total density in each comparison were tested for significance by Chi-square analysis, using one degree of freedom. Data for the unburned sections were considered to be the expected values; whereas, data for the burned sections were taken as observed values. Computations were Fortran-run on an IBM 360 Series Model 50 computer at Indiana State University.

Species nomenclature follows Fernald (1950).

RESULTS

The herbaceous stratum at St. Mary's was dominated by *Claytonia virginica* L. and *Viola* spp. (non-flowering individuals could not be separated) in both the unburned and burned sections, where the two species comprised 50 and 59% of the total density, respectively (Table 1). Fall burning had little effect, on the rate of vernalization at the time of either count. Significant differences in density did occur for 8 of the 10 species in the burned section, however (Table 1). The total density for all species was also significantly lower (627 *vs.* 569). Three taxa (*Viola* spp., *Ranunculus acris* L. and *Anemonella thalictroides* L.) increased in density in the burned section. Six of the remaining seven species experienced

TABLE 1.—Effects of fall burning on densities of spring wildflower populations at St. Mary's of the Woods, Vigo County, Indiana. (Counts are based on 32 plots each 1 m_2. Sampled May 2, 1972. Burned in late October 1971.)

Species	Total Density		% Change in Density	Relative Density	
	U	B		U	B
Claytonia virginica	216	179**	— 17	34.	32.
Viola spp.	96	155**	+ 61	15.	27. **
Dentaria laciniata	87	47*	— 46	14.	8.3
Dicentra spp.	72	65	— 10	12.	11.
Galium aparine	57	28**	— 51	9.1	4.9
Polygonatum pubescens	32	2**	— 94	5.1	0.4*
Ranunculus acris	26	44**	+ 69	4.1	7.7*
Galium concinnum	20	16	— 20	3.2	2.8
Podophyllum peltatum	12	3**	— 75	1.9	0.5
Anemonclla thalictroides	9	30**	+233	1.4	5.3**
Total	627	569*	— 9		
X Density per plot	19.6	17.8			

* Significant at the .05 level.
** Signifiiant at the .01 level.

significant decreases in the burned area. *Dicentra* spp. (the two species could not be positively separated in vegetative stage) decreased only slightly.

Frequency changes in response to burning were not as pronounced as those for density. Only *Viola spp.* and *A. thalictroides* increased significantly in frequency; *Dentaria laciniata* Muhl., *Polygonatum pubescens* Willd., *Podophyllum peltatum* L. and *Galium concinnum* T. & G. all had significantly lower frequency percentages (Fig. 1).

Five species other than spring wildflowers appeared in the herbaceous stratum at St. Mary's. These species doubled the total density in the unburned section and increased the density by over 50% in the burned portion. When all species were considered, the total density in the unburned area exceeded that in the burned area by 334 (1294 vs. 960). The herbaceous fragile fern (*Cystopteris fragilis* Bernh.) and blue wood aster (*Aster cordifolius* L.) had highly significant decreases in the burned section; whereas the woody Virginia creeper (*Parthenocissus quinquefolia* (L.) *Planch.)* increased significantly. Common cinquefoil (*Potentilla simplex* Michx.) and round-leafed greenbriar (*Smilax rotundifolia* L.) were present in the burned areas as infrequent species.

The Dennison, Illinois, herbaceous community on the unburned substrate was dominated by cut-leaf toothwort (*Dentaria laciniata*), may-apple (*Podophyllum peltatum*) and trout-lily (*Erythronium americanum* Ker.) which totalled 72% of stand density (Table 2). Major shifts in dominants occurred in the burned section. Toothwort was still the leading species, but *Viola* spp. and Jack-in-the-pulpit (*Arisaema atrorubens* (Ait.) Blume) increased greatly to become the second and third dominants. These three species totalled 65% of the relative density.

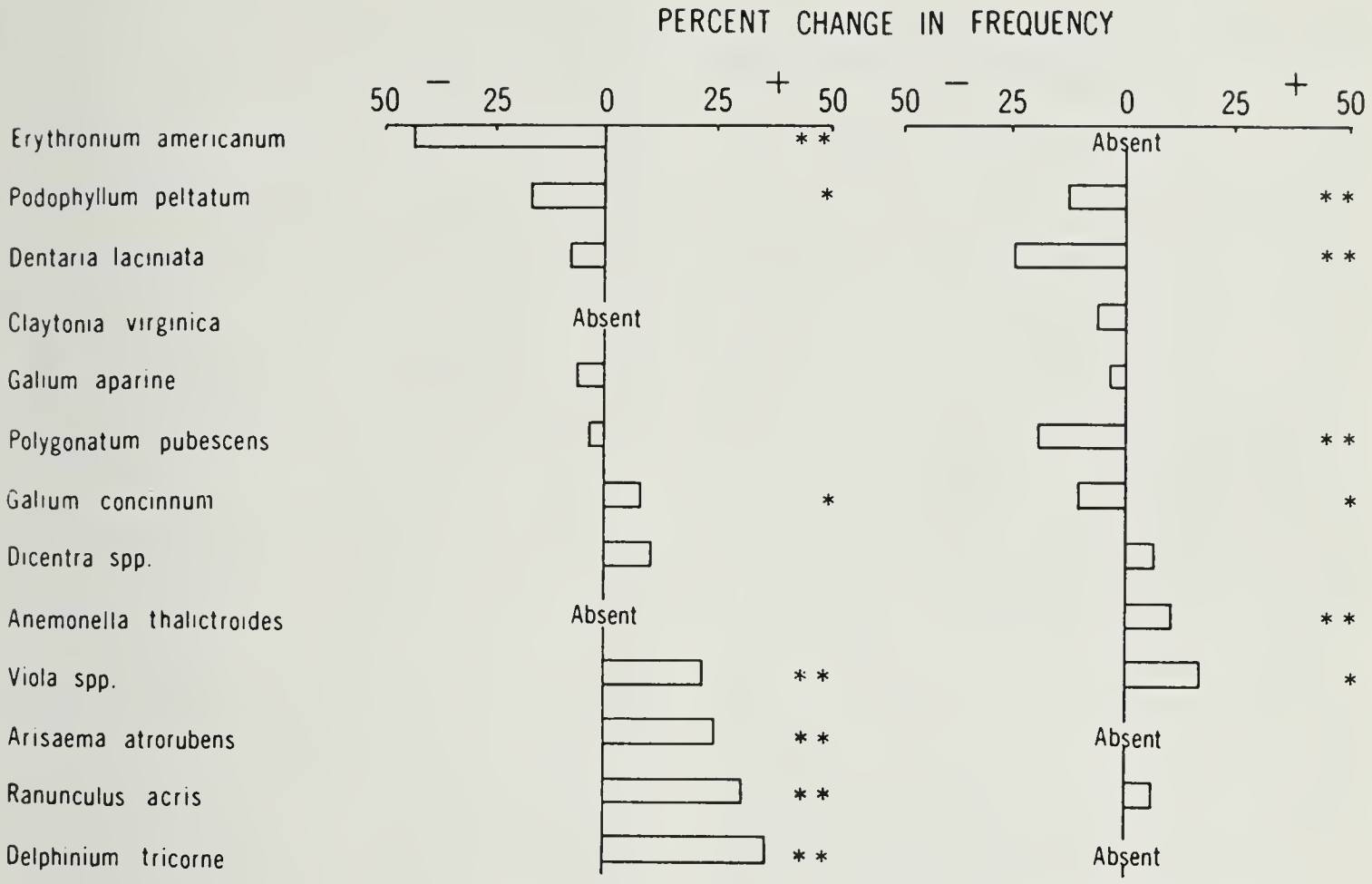

FIGURE 1. Changes in frequency of occurrence of spring herbs due to spring (left) and fall (right) burning. (*Significant at the .05 level; **Significant at the .01 level)

TABLE 2. Effects of spring burning on densities of spring wildflower populations at Dennison, Clark County, Illinois. (Counts ase based on 32 plots eash 1 m_2. Sampled May 6, 1972. Burned April 11, 1971.)

Species	Total Density		% Change in Density	Relative Density	
	U	B		U	B
Dentaria laciniata	463	320**	— 31	44.	32. *
Podophyllum peltatum	187	33**	— 83	18.	3.3**
Erythronium americanum	112	3**	— 97	11.	0.3**
Dicentra spp.	94	73	— 22	8.9	7.4**
Viola spp.	56	221**	+ 295	5.3	22. **
Galium aparine	44	34	— 23	4.2	3.4
Galium concinnum	27	44*	+ 63	2.6	4.4
Arisaema atrorubens	21	114**	+ 443	2.0	12. **
Ranunculus acris	19	72**	+ 279	1.8	7.3**
Polygonatum pubescens	17	15	— 12	1.5	1.5
Delphinium tricorne	14	61**	+ 336	1.3	6.2**
Total	1,054	990	— 6		
$\overline{X}$ Density per plot	32.9	30.9			

* Significant at the .05 level.
** Signilcant at the .01 level.

Spring burning, which destroyed the above-ground portions of most species, substantially retarded the rate of vernalization in the herbaceous stratum during the year following burning. The early Dennison count on April 14 revealed double the total density in the unburned area (1,398 *vs.* 713); the total species in the herbaceous stratum was reversed, however, with 8 in the unburned and 14 species in the burned portion of the tract. The second count (May 6) showed nearly equal total densities (1,487 *vs.* 1,470) and 11 *versus* 15 species.

Data for only the wildflower species are shown in Table 2. At the second count, 8 of the 11 species had significant or highly significant density changes in the burned section. Frequency values were significantly different for 7 species (Fig. 1). Five of the 11 species, *Viola* spp., pretty bedstraw (*G. concinnum*), Jack-in-the-pulpit (*A. atrorubens*), tall buttercup (*R. acris*), and rock larkspur (*Delphinium tricorne* Michx.) increased significantly. Jack-in-the-pulpit experienced major gains in density as a result of germination of many seeds in the burned section. The three dominant species all experienced significant decreases in density (Table 2), and two of the three had significantly lower frequencies (Fig. 1). The two *Dicentra* species, *G. aparine* L. and *P. pubescens,* all experienced minor density reductions. Three non-wildflower species recorded in the May 6 tally increased the total density by over 40% in each case to 1,487 and 1,470 in the unburned and burned areas, respectively. Virginia creeper was very common in the unburned and nearly absent in the burned area. Clearweed (*Pilea pumila* (L.) Gray) exhibited an opposite pattern. Fragile fern was present in only the burned area at a relatively high frequency and density.

Diversity changes were minor as indicated in Table 3. Fall burning at the St. Mary's area caused a slight decrease in diversity. Spring burning at the Dennison tract resulted in increased diversity at the end of a year following burning. Diversity changes resulted primarily from differences in the equitability component, as the species richness was identical in the burned and unburned sections at St. Mary's. Four additional species were found in the burned section at Dennison (not listed in Table 2), but each was represented by 10 or fewer individuals.

DISCUSSION

Although density and frequency differences for some herbaceous species may be due to chance, the changes reported here follow expected trends subsequent to burning. Three interesting patterns of change occurred at both study sites (Tables 1 and 2) : 1) Most wildflower species

TABLE 3. Diversity indices for unburned and burned sections at the two study sites. Diversity calculations follow Simpson (1949).

Community	Diversity Index
St. Mary's	
Unburned	.187
Burned	.204
Dennison	
Unburned	.249
Burned	.178

"typical" of relatively undisturbed forest areas had density declines of about 20% in the burned sections. Examples are *Podophyllum peltatum, Erythronium americanum, Dentaria laciniata, Dicentra* spp., *Claytonia virginica,* and *Galium aparine;* 2) Species that commonly occur in forested areas, but frequently occupy less stabilized sites increased in density by 60% or more following fire. Examples include the species of *Viola* considered collectively (some species may have actually declined, while others increased proportionally more), *Ranunculus acris, Delphinium tricorne* and *Parthenocissus quinquefolia*; and 3) Species that occur in disturbance forest sites were found only in the burned sections. Examples are *Smilax rotundifolia* and *Potentilla simplex.*

Our results are similar to the few earlier reports involving the effects of fire on understory species in common with our sites. Marked increases in burned forest lands have been reported for *Viola* (Ahlgren 1960), *Parthenocissus* (Oosting 1944) and *Smilax* (Lay 1956). Lemon (1949 reported increased diversity of forest herbs and lesser woody species. We found that spring burning slightly increased diversity but that fall burning did not (Table 3). Buell and Cantlon (1953) and Hodgkins (1958) found that cover of forest forbs increased during the first growing season following fire. Although we did not record cover, the "greenness" of burned sections was noticeably greater than in unburned areas. This resulted largely from substantial density increases in *Viola, Ranunculus, Arisaema* and *Delphinium,* and increased lushness of most species following fertilizing action of nutrients from the ash. Such changes in species composition and vitality control the nature of herbaceous succession following fire, but dominance by increaser or invader forbs may be short-lived as woody and grass cover increase (Oosting 1944; Hodgkins 1958).

Burning also influenced the ratio of non-flowering to flowering individuals for some species. The substantial increase in *Arisaema atrorubens* resulted from widespread germination of seeds after fire as few mature flowering individuals occurred in the burned area. Much of the density represented by *Dentaria* and *Claytonia* in the burned areas was also comprised of small, non-flowering individuals which probably represented first-year growth. Otherwise, density reductions in these species due to burning would have been greater. Increased light, mineralization of soil organic matter and the removal of the litter layer from the seedbed enhance germination of many forest species. Scarification of hard seeds by fire may improve germination success of some species. Little is known of the time span of viability of most wildflower seeds in the forest litter or soil. Burning sets back succession in the sub-canopy strata, and the survival strategy of species characteristic of earlier seral stages is rapid invasion into disturbance sites. Stimulated germination of stored seeds and rapid growth following burning would greatly favor such species relative to herbs typical of later stages.

On the other hand, perennial herbaceous species representative of more stabilized communities are largely vegetatively reproduced and would suffer reductions unless their reproductive parts were resistant to fire or well sheltered from fire by sufficient soil. Regeneration would then occur more slowly as seeds were brought in from unburned areas. Species with shallow corms or rhizomes should be most susceptible to fire, with corresponding reductions in chances of recovery by

vegetative reproduction. However, a ground fire that moves rapidly through dry litter probably does not heat the soil substantially to very deep levels for very long periods. Heyward (1938) found that fires in the longleaf pine region heated the upper inch of soil to only 175° F for 2-4 minutes. Moisture in the upper layers of organic forest soils, however, may form steam during ground fires. Such moist heat is more damaging to living tissue than dry heat from fires occurring on drier sites (Ahlgren 1960). This relationship may account for similar density and frequency changes observed in this study following both spring and fall burning. Soils were more moist from fall rains than was the case at the time of the spring fire. Steam produced underground by the fall fires could have killed even the dormant herbs. Most of the species experiencing the greatest density reductions at both sites have rather shallow perennating structures except *Erythronium*. Depletion of carbohydrate reserves due to spring burning may have reduced the recouperative capacity of surviving below-ground structures in that species.

The paucity of data on the effects of burning on forest herbs of this region indicates a need for additional study. Controlled burns of presampled areas, followed by relatively long term post-fire succession studies would answer many questions.

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PLANT COLLECTIONS OF ROLLO T. REXROAT

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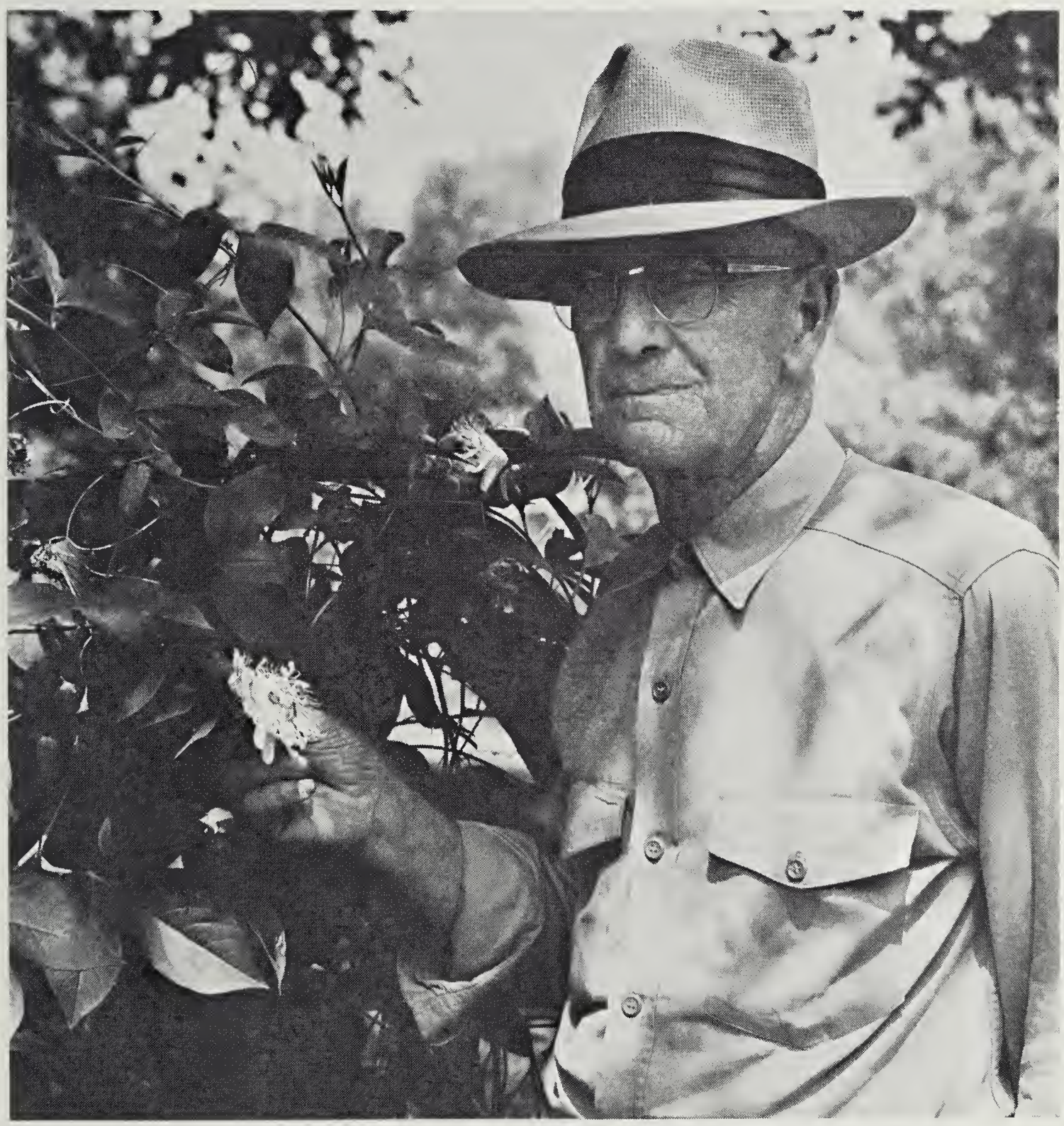
ABSTRACT: Mr. Rollo T. Rexroat, of Virginia, Illinois, has collected approximately 11,000 specimens of Illinois vascular plants and donated them to the herbarium of the Illinois State Museum. Fourteen species of vascular plants were first collected in Illinois by Mr. Rexroat. In addition, *Chorispora tenella* (Willd.) DC., *Miscanthus sinensis* Anderss., *Salvia verticillata* L., and *Ammannia auriculata* Willd. are reported herein for the first time. Four hundred and forty-five new county records of ferns and monocots are included.



Rollo T. Rexroat

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Mr. Rollo T. Rexroat of Virginia, Illinois, has collected and donated to the herbarium of the Illinois State Museum approximately 11,000 specimens of plants growing in Illinois. The pursuance of this hobby by Mr. Rexroat marked the beginning of many trips by him and Mrs. Rexroat to the State Museum with his latest boxes of pressed, dried plant specimens. The botanical material was not fragmentary and selected at random. Instead the specimens were the work of a person who observes, carefully selects, and then prepares the plants with pride, arranging leaves and flowers with the skill of an artist and the accuracy of a scientist.

It is perhaps natural that Rexroat's interest is in the plants of west-central Illinois counties since he was born near Virginia in 1893 and has lived near there all of his life. Mr. Rexroat's familiarity with the area led him into seldom visited and often poorly accessible places where some of the unusual and rarely collected Illinois plants still grow. His periodic contributions to the Museum thus often contained significant additions to the distributional data for Illinois plants and an occasional species new to the flora of the state. Mr. Rexroat maintains a duplicate unmounted set of specimens at his home.

Mr. Rexroat conservatively estimated that he has driven about forty thousand miles, adding "I walked about fifty thousand" (Winterringer, 1965). During the last seventeen years he has pursued this engrossing hobby and worked daily in his general store on the west side of the Virginia town square. His extensive travel has resulted in the collection of 20 sepcies which had not been seen in Illinois for nearly a century and an additional 40 species very infrequently collected.

Mr. Rexroat made the first Illinois collection of ten species of flowering plants which have been previously published. Four unpublished species are included in this account. Previously published species are *Anagallis arvense* forma *caerula* (Schreb.) Baumg. (Winterringer, 1963), *Arctium tomentosum* Mill. (Winterringer, 1957), *Cyperus grayioides* Mohl. (Mohlenbrock, 1959), *Eragrostis curvula* (Schrad.) Nees (Winterringer, 1961), *Eupatorium coelestinum* L. forma *album* E. J. Alex. (Wunderlin, 1966), *Falcaria sioides* (Wibel) Aschers. (Winterringer, 1958), *Fimbristylis vahlii* (Lam.) Link (Winterringer and Evers, 1960), *Lipocarpha maculata* (Michx.) Torr. (Winterringer, 1959), *Scleria reticularis* Michx. (Winterringer, 1958), and *Sitanion hystrix* (Nutt.) J. G. Smith (Mohlenbrock and Schwegman, 1969).

In addition to the aforementioned plants, Mr. Rexroat has collected four other species new to the flora of Illinois. These are reported here for the first time with pertinent data and are deposited in the Illinois State Museum Herbarium.

Family Cruciferae

Chorispora tenella (Willd.) DC. In cinders along the G.M.&O. railroad; Greene Co.; Roodhouse, Illinois; June 21, 1963; 8905; same locality; June 15, 1964; 9341. *C. tenella* is native in central Asia and is established as a weed in the drier western states. Gleason (1952) considers it to be an adventive in eastern United States and this collection confirms its occurrence in Illinois.

Family Gramineae

Miscanthus sinensis Anderss. Clay bank over 100 yards from any habitation; Cass Co.; west of Virginia; Oct. 14, 1959; 6476. *M. sinensis* is a native grass of China and is culti-

vated as an ornamental (Gleason, 1952) in Illinois. This collection indicates its ability to escape cultivation and survive in central Illinois.

FAMILY LABIATAE

Salvia verticillata L. In gravel and rock along the G.M.&O. railroad; Scott Co.; north of Manchester; June 21, 1963; 8878; same locality; June 15, 1964 9320. *S. verticillata* is native to southern and eastern Europe and western Asia but has been introduced into the eastern United States. Collections in succeeding years confirm its establishment in Scott County.

FAMILY LYTHRACEAE

Ammannia auriculata Willd. Growing in a wet sandy area, almost a sand pond; Cass Co.; 6 miles west of Virginia; August 10, 1967; 10455; same locality; Aug. 14, 1967; 10481-10485. *A. auriculata* is found in wet places from Indiana to Nebraska and Texas. The Cass Co. population is large enough to indicate that this species might have gone unnoticed for several years.

Examination of the ferns Mr. Rexroat collected has resulted in 15 new county records and similar study of the monocots has revealed 429 county records in addition to those already included in the *Flora of Illinois* (Jones, 1963); *Illustrated Flora of Illinois* (Mohlenbrock, 1967, 1970, 1970); *New Records for Illinois Vascular Plants* (Winterringer and Evers, 1960); and articles in various journals. The specimens confirming such distribution are cited below and are filed in the herbarium of the Illinois State Museum in Springfield, Illinois.

FAMILY POLYPODIACEAE

Athyrium angustum (Willd.) Presl.
Adams Co.; moist woods; 8840.
Greene Co.; ravine in woods; 7003.
Mason Co.; woods; 9840.
Morgan Co.; 4242.

Athyrium thelypterioides (Michx.) Desv.
Adams Co.; deep wooded ravine; 9214.
Greene Co.; deep ravine in woods; 6956.

Cystopteris bulbifera (L.) Bernh.
Schuyler Co.; cool creek on damp shaded rocks; 8277.

Dryopteris cristata (L.) A. Gray
Mason Co.; brushy thicket in black sandy soil; 10209.

Dryopteris intermedia (Muhl.) A. Gray
McDonough Co.; creek bank in woods; 9972.

Onoclea sensibilis L.
Greene Co.; creek bank in woods; 6674.
Pike Co.; open roadside bank; 9615.

Pteridium latiusculum (Desv.) Hieron.
Scott Co.; sandy woods; 3629.

Woodsia obtusa (Spreng.) Torr.
Macoupin Co.; creek bank of moist, sandy clay; 8343.

FAMILY SALVINIACEAE

Azolla mexicana Presl.
Brown Co.; water; 4499.
Pike Co.; ditch; 6190.

FAMILY ALISMACEAE

Sagittaria calycinus Engelm.
Cass Co.; shallow water; 5323.
Morgan Co.; mud and water; 4486.
Scott Co.; river bank in mud; 4474.

Sagittaria graminea Michx.
Mason Co.; sand pond; 5210.

Sagittaria rigida Pursh
Cass Co.; peaty muddy sand; 4398.

FAMILY AMARYLLIDACEAE

Hypoxis hirsuta (L.) Coville
Fulton Co.; mossy clay hillside; 4665.

FAMILY ARACEAE

Acorus calamus L.
Brown Co.; moist valley; 3719.
Macoupin Co.; wet draw; 9484.
Scott Co.; wet area; 3837.

FAMILY COMMELINACEAE

Commelina communis L.
Mason Co.; moist shady area; 6360.
Schuyler Co.; bank of creek; 9244.
Commelina erecta L.
Fulton Co.; sandy soil; 6062.
Tradescantia bracteata Small
Greene Co.; along railroad; 9127.
Menard Co.; 7720.
Tradescantia ohiensis Raf.
Schuyler Co.; sandy soil; 1701.
Tradescantia subaspera Ker.
Greene Co.; moist, heavy shade; 6930.
Morgan Co.; wooded hillside; 8259.
Scott Co.; sandy shaly moist hillside; 3872.
Tradescantia virginiana L.
Fulton Co.; sandy clay hillside; 4659.
Morgan Co.; 8790.

FAMILY CYPERACEAE

Carex albolutescens Schw.
Cass Co.; wet valley; 10333.
Greene Co.; cinders of railroad; 9991.
Carex albursina Sheldon
Greene Co.; rocky wooded north hillside; 6656.
Schuyler Co.; rocky, wooded north hillside; 5687.
Carex alopecoidea Tuckerm.
Greene Co.; creek bank; 6756.
McDonough Co.; wet; 7549.
Carex artitecta Mack.
Greene Co.; thin woods; 6671.
Mason Co.; dry sand; 7473.
Carex bebbii Olney
Brown Co.; gravelly soil; 2685.
Carex bicknellii Britt.
Cass Co.; wet peaty sand; 4966.
Carex brachyglossa Mack.
Cass Co.; moist peaty sand; 8263.
Carex buxbaumii Wahl.
Menard Co.; moist valley in full sun; 4690.
Carex cephaloidea Dewey
Brown Co.; deep valley in woods; 3705.
Carex communis Bailey
Schuyler Co.; growing on side of gulley in deep woods; 3670.
Carex comosa Boott
Menard Co.; wet peaty swamp; 4711.
Carex conjuncta Boott
Mason Co.; wet mucky soil; 5805.
Carex conoidea Schk.
Morgan Co.; sandy, clay woods; 5896.
Carex crinita Lam.
Adams Co.; wet swale; 8852.
Carex cristatella Britt.
Greene Co.; wet valley; 8303.
Pike Co.; wet shore of pond; 5878.
Carex cruscorvi Shuttlw.
Mason Co.; moist sandy soil; 7788.
Morgan Co.; low moist ground; 8183.
Carex davisii Schw. & Torr.
Brown Co.; shady hillside; 2692.
Carex emoryi Dewey
Cass Co.; wet, springy area; 7481.
Carex festucacea Schk.
Greene Co.; dry hillside in thin woods; 6799.
Schuyler Co.; foot of sand levee; 2668.
Carex frankii Kunth
Brown Co.; low ground; 6005.
Fulton Co.; moist area; 6057.
Carex gracilescens Steud.
Cass Co.; wet mucky sand in woods; 6852.
Carex gravida Bailey
Brown Co.; dry, rocky hillside; 2703.
Carex grayii Carey
Cass Co.; river bottom; 4246.
Carex grisea Wahl.
Brown Co.; shady hillside; 2691.
McDonough Co.; wet; 7544.
Scott Co.; rocky hillside in shade; 3726.

Carex haydenii Dewey
Cass Co.; swampy sand area: 10272.
Carex hirsutella Mack.
Morgan Co.; sandy clay hillside; 3851.
Scott Co.; moist; 3756.
Carex hirtifolia Mack.
Greene Co.; shady, wooded hillside; 6751.
Mason Co.; edge of sand pond; 4924.
Morgan Co.; low on a hillside in woods; 3843.
Schuyler Co.; woods; 7586.
Scott Co.; rocky hillside; 3754.
Carex hitchcockiana Dewey
Schuyler Co.; rocky, wooded hillside; 5686.
Scott Co.; shaded rocky hillside; 3731.
Carex hyalinolepis Steud.
Mason Co.; low ground-sandy; 109.
Carex hystricina Muhl.
McDonough Co.; wet; 7550.
Scott Co.; wet ditch bank; 7782.
Carex interior Bailey
Menard Co.; peaty springy swamp; 4712.
Carex jamesii Schw.
Adams Co., wooded hillside; 8717.
Brown Co.; shady hillside; 2694.
Cass Co.; 5780.
McDonough Co.; wooded hillside; 7547.
Schuyler Co.; rocky wooded hillside; 5837.
Scott Co.; hillside; 3729.
Carex lacustris Willd.
Mason Co.; low ground; 5695.
Carex laeviconica Dewey
Cass Co.; moist sandy soil; 3787.
Pike Co.; moist; 5699.
Carex lasiocarpa Ehrh.
Cass Co.; peaty sand; 4856.
Carex lupuliformis Sartw.
Brown Co.; low ground; 5999.
Carex lurida Wahl.
Cass Co.; wet; 6039.
Scott Co.; moist hillside; 3740.
Carex meadii Dewey
Cass Co.; moist sand; 4852.
Carex muskingumensis Schw.
Cass Co.; low ground; 3000.
Carex normalis Mack.
Cass Co.; black sandy mucky soil; 8761.
Carex pallescens L.
Fulton Co.; gravelly clay sterile hillside; 5034.
Carex pensylvanica Lam.
Brown Co.; wooded hillside; 6831.
Cass Co.; sandy; 4854.
Schuyler Co.; clay bank in shade; 6747.
Carex platyphylla Carey
Mason Co.; low, sandy woods; 7648.
Carex prairea Dewey
Greene Co.; sand and cinders along a railroad; 9952.
Carex retrorsa Schw.
Fulton Co.; gravelly in wet sand; 4793.
Carex richardsonii R.Br.
Cass Co.; north side of loess bluff; 4723.
Mason Co.; sand dune; 4642.
Carex rosea Schk.
Brown Co.; north hillside; 2695.
Pike Co.; woods; 5728.
Scott Co.; moist shady area; 3728.
Carex scoparia Schk.
Pike Co.; low ground; 5858.
Schuyler Co.; moist; 5839.
Carex sparganioides Muhl.
Brown Co.; shady hillside; 2693.
Carex stipata Muhl.
Brown Co.; riverbank; 2665.
Carex stricta Lam.
Cass Co.; 872.
Mason Co.; swamp; 4765.
Carex swanii (Fern.) Mack.
Pike Co.; sandy clay hillside in thin woods; 5716.
Carex tenera Dewey
Mason Co.; moist sand pond; 4991.
Carex tetanica Schk.
Pike Co.; ravine in woods; 5735.
Schuyler Co.; 1452.

Carex texensis (Torr.) Bailey
Cass Co.; in shade among grasses; 9312.
Carex tribuloides Wahl.
Scott Co.; ditch; 4453.
Carex umbellata Schk.
Cass Co.; north side of high loess hill; 4724.
Schuyler Co.; sterile north hillside; 6730.
Carex vesicaria L.
Brown Co.; wet; 2657.
Mason Co.; wet; 4946.
Carex virescens Muhl.
Cass Co.; edge of pond; 5246.
Cyperus acuminatus Torr. & Hook.
Morgan Co.; along railroad tracks in black soil; 9368.
Pike Co.; low ground; 6367.
Schuyler Co.; mud; 8088.
Cyperus aristatus Rottb.
Brown Co.; low ground once submerged; 5310.
Fulton Co.; mud flat over sand; 6226.
Morgan Co.; moist sandy beach; 3251.
Schuyler Co.; Long Lake; 6464.
Scott Co.; sandy, moist beach; 6409.
Cyperus diandrus Torr.
Morgan Co.; moist, sandy beach; 6406.
Scott Co.; moist, sandy beach; 6407.
Cyperus erythrorhizos Muhl.
Greene Co.; mud flat of river bank; 7307.
Schuyler Co.; moist; 6145.
Scott Co.; river bottom mud; 4469.
Cyperus esculentus L.
Brown Co.; river bottom cornfield; 4501.
Morgan Co.; moist; 6523.
Cyperus ferruginescens Boeck.
Morgan Co.; sandy beach; 3250.
Pike Co.; low, moist ground; 6129.
Cyperus filiculmis Vahl. var. *filiculmis*
Morgan Co.; dry sandy soil; 3030.
Cyperus filiculmis Vahl. var. *macilentus* Fern.
Greene Co.; cinders along railroad tracks; 8874.
Cyperus flavescens L.
Mason Co.; low, wet area in sand hills; 7131.
Cyperus ovularis (Michx.) Torr.
Menard Co.; sand; 4934.
Morgan Co.; along a railroad; 9944.
Pike Co.; dry sand; 6112.
Scott Co.; blow sand; 7228.
Cyperus rivularis Kunth
Cass Co.; wet sand; 5176.
Menard Co.; wet sandy hillside; 5539.
Morgan Co.; sandy beach; 3254.
Scott Co.; sandy beach; 6417.
Cyperus schweinitzii Torr.
Fulton Co.; river bank; 6065.
Pike Co.; dry sand; 6111.
Cyperus strigosus L.
Brown Co.; moist; 6338.
Eleocharis acicularis (L.) R. & S.
Greene Co.; dry pond; 9243.
Eleocharis compressa Sulliv.
Cass Co.; moist peaty soil; 7659.
Scott Co.; ditch; 9324.
Eleocharis equisetoides (Ell.) Torr.
Cass Co.; shallow water near edge of natural sand pond; 10449.
Eleocharis erythropoda Steud.
Cass Co.; swamp; 7714.
Scott Co.; wet peaty soil; 5981.
Eleocharis obtusa (Willd.) Schult.
Brown Co.; low ground; 6334.
Eleocharis ovata (Roth) R. & S.
Mason Co.; wet; 5820.
Eleocharis palustris (L.) R. & S.
Morgan Co.; moist peaty soil; 5915.
Eleocharis tenuis (Willd.) Schult.
Mason Co.; edge of sand pond; 5490.
Scott Co.; along railroad tracks in moist area; 9325.
Hemicarpha micrantha (Vahl) Pax
Scott Co.; moist sandy beach; 6408.
Scirpus acutus Muhl.
Pike Co.; shallow water; 5872.

Scirpus cyperinus (L.) Kunth.
Morgan Co.; muddy; 8398.
Scirpus fluviatilis (*Torr.*) A. Gray
Greene Co.; wet; 7041.
Scirpus validus Vahl
Greene Co.; wet; 6928.
Morgan Co.; wet; 5995.
Pike Co.; shallow water; 6025.
Scleria triglomerata Michx.
Adams Co.; high, dry hill over limestone; 9206.

FAMILY DIOSCOREACEAE

Dioscorea villosa L.
Scott Co.; sandy soil; 3906.

FAMILY GRAMINEAE

Aegilops cylindrica Host.
Greene Co.; edge of railroad tracks; 9331.
Agropyron smithii Rydb.
Cass Co.; cinders along railroad tracks; 4967.
Greene Co.; along railroad tracks; 8901.
Menard Co.; ballast along railroad tracks; 9761.
Agrostis hyemalis (Walt.) BSP.
Schuyler Co.; dry, wooded hillside; 7349.
Scott Co.; dry, rocky mossy hillside; 7673.
Agrostis perennans (Walt.) Tuckerm.
Greene Co.; wooded hillside; 8080.
Morgan Co.; opening in sandy woods; 7968.
Pike Co.; dry, sterile hill in thin woods; 9498.
Schuyler Co.; growing on a mossy, wet rock; 7353.
Agrostis scabra Willd.
Menard Co.; dry sandy soil; 6393.
Alopecurus carolinianus Walt.
Brown Co.; low field; 6819.
Pike Co.; wet soil; 5707.
Andropogon virginicus L.
Macoupin Co.; clay hillside; 8604.
Aristida basiramea Engelm.
Menard Co.; cinders along a railroad; 10063.
Aristida curtissii (A. Gray) Nash
Cass Co.; sand and cinders; 8676.
Aristida desmantha Trin. & Rupr.
Menard Co.; sandy hillside; 5541.
Aristida dichotoma Michx.
Adams Co.; red clay hillside; 9588.
Cass Co.; dry reddish clay; 5450.
Scott Co.; rocky, gravelly clay hillside; 8019.
Aristida intermedia Scribn. & Ball
Cass Co.; low sandy area; 9669.
Aristida longespica Poir.
Adams Co.; dry, poor soil; 9149.
Morgan Co.; clay hillside; 4506.
Pike Co.; dry open hillside in woods; 9500.
Schuyler Co.; dry sterile hillside; 7352.
Scott Co.; rocky, sterile clay hillside; 8018.
Aristida oligantha Michx.
Greene Co.; along railroad tracks; 9226.
Aristida tuberculosa Nutt.
Scott Co.; dry land; 7313.
Arrhenatherum elatius (L.) Mert. and Koch.
Schuyler Co.; ditch along railroad in sand; 10625.
Bouteloua gracilis (HBK.) Lag.
Morgan Co.; along C.B.&Q. railroad; 9945.
Brachyelytrum erectum (Schreb.) Beauv.
Adams Co.; valley in woods; 9208.
Cass Co.; moist shady hillside in woods; 7333.
Morgan Co.; thin woods; 10519.
Bromus inermis Leyss.
McDonough Co.; sandy clay soil in thin woods; 7635.
Bromus japonicus Thunb.
Morgan Co.; along a railroad; 9808.
Bromus latiglumis (Shear) Hitchc.
Cass Co.; base of wooded hillside; 10201.
Bromus purgans L.
Cass Co.; partial shade; 8906.
Mason Co.; woods; 9838.

Bromus secalinus L.
Cass Co.; dry ditch with peaty sand; 4970.
Morgan Co.; sandy soil; 8184.
Calamagrostis canadensis (Michx.) Beauv.
Cass Co.; shaded, mucky sand almost in water; 6854.
Schuyler Co.; shady draw; 8362.
Cenchrus pauciflorus Benth.
Greene Co.; gravelly soil; 7018.
Chloris verticillata Nutt.
Cass Co.; sand; 9257.
Greene Co.; along railroad; 9328.
Mason Co.; sand; 9664.
Cinna arundinacea L.
Greene Co.; moist creek valley; 6967.
Cynodon dactylon (L.) Pers.
Greene Co.; cinders of railroad; 10219.
Scott Co.; rocky place along railroad; 9068.
Dactylis glomerata L.
Mason Co.; moist black sandy soil; 10434.
Danthonia spicata (L.) Beauv.
Adams Co.; sterile hillside in thin woods; 8844.
Schuyler Co.; dry hillside in sandy clay; 7594.
Scott Co.; sterile mossy hill in thin woods; 7676.
Diarrhena americana Beauv.
Cass Co.; woods; 4426.
Digitaria filiformis (L.) Koel.
Mason Co.; sand 10074.
Scott Co.; side of blow sand hill; 7262.
Digitaria ischaemum (Schreb.) Muhl.
Greene Co.; moist; 7243.
Digitaria sanguinalis (L.) Scop.
Greene Co.; along railroad; 9995.
Echinochloa walteri (Pursh) Heller
Brown Co.; low ground; 6355.
Elymus canadensis L.
Scott Co.; sandy roadside; 3917.
Elymus villosus Muhl.
Cass Co.; north hillside in heavy woods; 10494.
Eragrostis cilianensis (All.) Lut.
Brown Co.; low ground; 6353.
Morgan Co.; along a railroad; 9943.
Eragrostis frankii C.A.Meyer
Brown Co.; Illinois River bottomland; 5309.
Cass Co.; river bank at the La Grange locks; 8690.
Greene Co.; moist gravelly soil; 7094.
Mason Co.; alluvial soil; 5547.
Scott Co.; river bank; 9571.
Eragrostis hypnoides (Lam.) BSP.
Brown Co.; low moist ground; 6349.
Scott Co.; wet; 6429.
Eragrostis pectinacea (Michx.) Nees
Scott Co.; dry, hard gravelly roadside soil; 8408.
Eragrostis poaeoides (L.) Beauv.
Cass Co.; dry sandy soil; 5519.
Mason Co.; in sand at bottom of blowhole; 3974.
Morgan Co.; low fallow field; 5979.
Eragrostis spectabilis (Pursh) Steud.
Schuyler Co.; moderately dry sand; 8498.
Scott Co.; side of blow sand hill; 7261.
Festuca elatior L.
Macoupin Co.; opening in woods on hillside; 8240.
Menard Co.; moist valley; 5534.
Festuca obtusa Biehler
Cass Co.; black soil in shade; 3775.
Pike Co.; wooded ravine; 5727.
Festuca octoflora Walt.
McDonough Co.; dry sandy soil; 7521.
Schuyler Co.; wooded, sterile north hillside; 6731.
Glyceria septentrionalis Hitchc.
Pike Co.; moist soil; 5864.
Glyceria striata (Lam.) Hitchc.
Brown Co.; wet; 5850.
Pike Co.; moist shady valley; 5965.
Hystrix patula Moench
Greene Co.; 6875.
Menard Co.; dry woods; 6385.

Koeleria cristata (L.) Pers.
Morgan Co.; sandy clay hill; 3845.
Leersia virginica Willd.
Greene Co.; moist shade; 7158.
Morgan Co.; low, shaded ground; 7964.
Leptochloa fascicularis (Lam.) A. Gray
Greene Co.; along railroad in rocky cinders; 9070.
McDonough Co.; along a railroad; 10018.
Mason Co.; cinders and ballast along a railroad; 10438.
Morgan Co.; along railroad in cinders; 9426.
Pike Co.; along railroad in cinders; 9909.
Lolium multiflorum Lam.
Greene Co.; along railroad; 8902.
Muhlenbergia asperifolia (Nees & Mey.) Parodi
Cass Co.; cinders along a railroad; 10036.
Menard Co.; cinders along a railroad; 10176.
Morgan Co.; cinders along a railroad; 10635.
Muhlenbergia cuspidata (Torr.) Rydb.
Cass Co.; north side of sandy clay bluff; 7210.
Panicum clandestinum L.
Adams Co.; creek valley; 8834.
Mason Co.; hillside in sandy woods; 7649.
Scott Co.; base of hill; 7670.
Panicum depauperatum Muhl.
Schuyler Co.; dry hilltop at edge of woods; 7595.
Scott Co.; moist; 7679.
Panicum dichotomiflorum Michx.
Brown Co.; riverbank mud; 4503.
Cass Co.; 9092.
Scott Co.; riverbank mud; 4473.
Panicum implicatum Scribn.
Cass Co.; moist peaty sand; 7570.
Panicum lindheimeri Nash
Cass Co.; swampy, black sandy soil; 8485.
Greene Co.; dry hill; 7008.
Menard Co., moist sand; 5513.
Panicum microcarpon Muhl.
Fulton Co.; moist, gravelly clay bank; 4918.
Panicum miliaceum L.
Greene Co.; along railroad in sand & cinders; 9343.
Panicum oligosanthes Schult.
Cass Co.; top of high sandy, loess hill; 8764.
Menard Co.; prairie soil in moist area; 7739.
Morgan Co.; high, sandy, loess bluff; 8172.
Scott Co.; sandy bank; 3619.
Panicum scribnerianum Nash
Fulton Co.; dry soil; 4791.
Panicum sphaerocarpon Ell.
Greene Co.; dry hillside; 7006.
Macoupin Co.; mossy hill top in thin woods; 8294.
Panicum tennesseense Ashe
McDonough Co.; thin woods of dry hillside; 7638.
Menard Co.; moist sand; 4933.
Schuyler Co.; dry, rocky clay hillside; 8270.
Scott Co.; sandy shaly clay hillside; 3823.
Panicum virgatum L.
Morgan Co.; moist area along G.M.&O. railroad; 9112.
Scott Co.; low ground; 4462.
Panicum wilcoxianum Vasey
Scott Co.; sandy; 3915.
Paspalum fluitans (Ell.) Kunth
Cass Co.; river bank; La Grange Locks; 8691.
Phalaris arundinacea L.
Morgan Co.; moist creek valley; 8177.
Phragmites communis Trin.
Scott Co.; ditch bank; 7781.
Poa annua L.
Fulton Co.; hillside; 4664.
Poa chapmaniana Scribn.
Mason Co.; top of levee; 10268.
Poa compressa L.
Morgan Co.; black, sandy soil; 5923.
Scott Co.; sand ridge; 7270.

Poa palustris L.
Adams Co.; hard poor soil; 8825.
Cass Co.; wet valley in woods; 7484.
Macoupin Co.; open place in woods; 8243.
Morgan Co.; yellow clay bank; 4507.

Poa sylvestris A. Gray
Brown Co.; rocky, mossy wooded hillside; 5674.
Cass Co.; wet peaty sand in woods; 7574.
McDonough Co.; sandy clay bank; 7636.
Schuyler Co.; deep ravine along a creek; 6735.
Scott Co.; moist valley in woods; 3819.

Setaria italica (L.) Beauv.
Cass Co.; roadside; 10389.
Menard Co.; wet sandy soil; 5197.
Morgan Co.; railroad bank; 10453.

Setaria verticillata (L.) Beauv.
Cass Co.; in an alley; 2475.
Mason Co.; black, sandy soil near river; 10230.

Setaria viridis (L.) Beauv.
Schuyler Co.; sand and cinders along a railroad; 9251.

Sorghum halepense (L.) Pers.
Fulton Co.; dry area; 6075.
Menard Co.; moist sandy soil; 5566.
Scott Co.; ditch along a road; 9506.

Sorghum vulgare Pers.
Cass Co.; edge of sandy swamp; 8422.
Fulton Co.; low pasture; 6242.
Greene Co.; waste ground; 7098.
Mason Co.; along the Illinois River; 10233.
Menard Co.; 10139.

Spartina pectinata Link.
Scott Co.; moist; 4192.

Sphenopholis intermedia Rydb.
Greene Co.; moist; 6774.

Sphenopholis obtusata (Michx.) Scribn.
Mason Co.; sandy soil; 8767.
Schuyler Co.; dry woods; 7591.
Scott Co.; prairie soil along a railroad; 9735.

Sporobolus asper (Michx.) Kunth
Greene Co.; along railroad tracks; 7329.
Scott Co.; 4384.

Sporobolus clandestinus (Biehler) Hitchc.
Menard Co.; sandy wooded hillside; 5569.
Schuyler Co.; railroad tracks; 5215.

Sporobolus cryptandrus (Torr.) A. Gray
Fulton Co.; sandy and dry; 6066.

Sporobolus heterolepis A. Gray
Mason Co.; black sandy soil; 7886.
Menard Co.; prairie soil along railroad; 10050.

Sporobolus neglectus Nash
Cass Co.; sand and cinders along railroad; 8685.
Mason Co.; abandoned railroad; 10393.

Sporobolus vaginiflorus (Torr.) Wood
Cass Co.; moist clay; 7332.
Greene Co.; 9078.
Pike Co.; gravelly clay; 10094.
Scott Co.; moist sandy clay; 4293.

Triplasis purpurea (Walt.) Chapm.
Brown Co.; river bank in dry sand; 6347.
Fulton Co.; dry, sandy river bank; 6210.
Scott Co.; dry sandy soil; 4336.

Tripsacum dactyloides L.
Scott Co.; along railroad; 4047.

FAMILY HYDROCHARITACEAE

Elodea occidentalis (Pursh) St. John
Cass Co.; water; 5929.
Greene Co.; shallow water; 7104.
Schuyler Co.; ditch; 2270.

FAMILY IRIDACEAE

Belamcanda chinensis (L.) DC.
Fulton Co.; bluffs; 5060.
Morgan Co.; clay soil; 8014.

Iris brevicaulis Raf.
Brown Co.; wooded hillside; 5853.
Mason Co.; 8198.
Menard Co.; low ground; 8200.
Scott Co.; shady north hillside; 4922.
Iris shrevei Small
Morgan Co.; wet ditch; 2750.
Sisyrinchium albidum Raf.
Adams Co.; along stream in thin woods; 8727.
Greene Co.; dry hillside; 6710.
McDonough Co.; moist, shady valley; 7554.
Menard Co.; dry ,black prairie soil; 4624.
Scott Co.; rocky hillside; 3755.
Sisyrinchium atlanticum Bickn.
Brown Co.; 2656.
Sisyrinchium bermudiana L.
Brown Co.; moist and sunny; 5823.
Sisyrinchium campestre Bickn.
Menard Co.; high sandy clay hill; 4622.
Scott Co.; dry sand; 3641.

FAMILY JUNCACEAE

Juncus biflorus Ell.
Cass Co.; sandy loam; 5601.
Juncus dudleyi Wieg.
Brown Co.; wet; 5828.
Juncus interior Wieg.
Morgan Co.; black, sandy soil; 5924.

FAMILY LILIACEAE

Allium mutabilis Michx.
Greene Co.; sand and cinders along railroad; 9333.
Mason Co.; low, sandy brush thicket; 10316.
Allium tricoccum Ait.
Fulton Co.; woods; 4912.
Asparagus officinalis L.
Schuyler Co.; 8268.
Hemerocallis fulva L.
Fulton Co.; moist roadside; 5078.
Menard Co.; 4953.
Pike Co.; roadside; 9884.
Ornithogalum umbellatum L.
Brown Co.; hillside in woods; 3700.
Scott Co.; creek bottom; 3564.
Smilax ecirrhata (Engelm.) Wats.
Cass Co.; woods; 92.
Morgan Co.; woods; 3613.
Pike Co.; woods; 5658.
Smilax hispida Muhl.
Schuyler Co.; moist thin woods; 6618.
Smilax illinoensis Mangaly
Greene Co.; woods; 6699.
Smilax lasioneura Hook.
Morgan Co.; 1604.
Trillium gleasoni Fern.
Fulton Co.; base of north hillside; 4619.
Schuyler Co.; base of northwest hillside; 7581.
Trillium nivale Riddell
Brown Co.; wooded hillside; 5675.
Uvularia grandiflora Sm.
Mason Co.; woods; 7998.
Scott Co.; woods; 3592.
Yucca filamentosa L.
Brown Co.; roadside bank; 3068.
Cass Co.; dry, sandy area; 941.
Macoupin Co.; gravelly clay hillside; 8219.
Mason Co.; sand; 954.
Menard Co.; sandy soil along side road; 5016.
Schuyler Co.; clay hillside; 2903.
Scott Co.; side of ravine in clay soil; 3874.

FAMILY ORCHIDACEAE

Aplectrum hyemale (Muhl.) Torr.
Cass Co.; thin woods; 6652.
Mason Co.; low sand woods; 9706.
Corallorhiza odontorhiza (Willd.) Nutt.
Cass Co.; rich, moist, black, sandy woods; 9269.
Greene Co.; wooded hillside; 8066.
Mason Co.; sandy alluvial soil; 9285.
Pike Co.; wooded hillside in gray clay soil; 8558.
Corallorhiza wisteriana Conrad
Scott Co.; woods in loamy, sandy soil; 7451.
Cypripedium parviflorum Salisb.
Schuyler Co.; woods; 10644.

Goodyera pubescens (Willd.) R. Br.
Mason Co.; low, river birch thicket; 10248.
Habenaria flava (L.) R. Br.
Cass Co.; woods; 8806.
Habenaria huronensis (Nutt.) Spreng.
Mason Co.; moist woods; 6955.
Habenaria lacera (Michx.) Lodd.
Adams Co.; dry soil on a flat hill top; 8812.
Liparis loeselii (L.) Rich.
Cass Co.; wet sandy soil; 10360.
Orchis spectabilis L.
Greene Co.; woods; 7468.
Schuyler Co.; woods; 7756.
Spiranthes cernua (L.) Rich.
Brown Co.; hillside in clay; 6624.
Scott Co.; high loess hillside; 4411.
Spiranthes gracilis (Bigel.) Beck
McDonough Co.; dry, grassy hillside; 8064.
Morgan Co.; dry clay hillside; 4307.
Pike Co.; clay hill; 6249.
Spiranthes ovalis Lindl.
Cass Co.; valley between high bluffs; 8007.

FAMILY POTAMOGETONACEAE

Potamogeton americanus C. & S.
Scott Co.; 7680.
Potamogeton crispus L.
Fulton Co.; Anderson Lake; 6444.
Potamogeton diversifolius Raf.
Mason Co.; sand pond in shallow water and on mud; 7192.
Pike Co.; on "watery mud" where water level had gone down; 5936.
Potamogeton foliosus Raf.
Pike Co.; in shallow water; 5941.
Potamogeton pectinatus L.
Cass Co.; in an old isolated pond (10-15 years old); 10392.
Potamogeton pusillus L.
Cass Co.; in deep water; 8191.
Zannichellia palustris L.
Schuyler Co.; in clear, cool water; 6162.

FAMILY SPARGANIACEAE

Sparganium americanum Nutt.
Fulton Co.; shallow water; 5788.
Pike Co.; wet; 5942.
Sparganium androcladum (Engelm.) Morong.
Schuyler Co.; drainage ditch; 6161.
Sparganium chlorocarpum Rydb.
Schuyler Co.; water in a ditch; 3124.
Sparganium eurycarpum Engelm.
Brown Co.; swampy; 4497.

FAMILY TYPHACEAE

Typha angustifolia L.
McDonough Co.; wet; 7814.

FAMILY XYRIDACEAE

Xyris torta Sm.
Cass Co.; peaty sand; 4136.

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COPROPHILOUS ASCOMYCETES OF ILLINOIS. I. PYRENOMYCETES

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ABSTRACT.—A preliminary taxonomic survey of the coprophilous ascomycetes of east central Illinois has yielded 29 species of seven genera of pyrenomycetes. Twenty-three of these species are not reported from Illinois in the available accounts of Illinois fungi or of coprophilous fungi. Also included are five species indentified by Lane (1951).

Introduction

The coprophilous ascomycetes, belonging to several orders, represent a large and heterogeneous group of ascomycetous fungi united by their affinities for animal dung. These fungi develop readily under laboratory conditions on herbivore dung collected at any time of year.

This study has been primarily undertaken to determine the relative abundance and number of species of coprophilous ascomycetes in Illinois, and has thus far been restricted to counties in the east central portion of the state. The orders treated here are included in the series Pyrenomycetes as defined in the restricted sense by Alexopoulos (1962). Coprophilous representatives of other orders will be treated in the future.

Previous knowledge of this group of fungi in Illinois has been primarily restricted to Lane's (1951) unpublished report of the coprophilous pyrenomycetes in the Champaign area of the state. Five species recorded by Lane but not found during this study are included, although no specimens of his collections have been located.

Materials and Methods

Over 10 collections of dung have been examined during this study, including material from cow (C), deer (D), goat (G), guinea pig (GU), horse (H), raccoon (RA), sheep (S), squirrel (SQ), tame rabbit (TR), and wild rabbit (R). The above abbreviations have been used in the species list to indicate the substrata that each species has been recorded on.

Dung samples were either incubated immediately after collection or air dried and stored for one to several months before incubation. Petri dishes and one-pint freezer containers, lined with filter paper or paper towels, served as incubation chambers. Samples were maintained in normal room light and temperature (21° C – 23° C) throughout the incubation period, which usually lasted four to eight weeks. Sterile water was used to keep the samples moist.

The number in parentheses following each species in the list indicates the number of times that species has appeared. Species followed by an asterisk were identified only by Lane (1951). Dried specimens, preserved material, or permanent slides of most species are in the herbarium of the University of Illinois or the author's herbarium. In a few cases, when all material of a species was needed for identification, camera lucida drawings were made for documentation.

The most useful keys for identifying members of the Chaetomiales are those of Chivers (1915), Skolko and Groves (1953), Ames (1961), and Seth (1971). Coprophilous species of the Sphaeriales can best

be identified using the keys of Griffiths (1901), Lundqvist (1972), Cain (1934), and Mirza and Cain (1969). The nomenclature used for the Sphaeriales in the last two references has been adopted here.

DISCUSSION

The collection of *Nectria coccinea* (Pers. ex Hook.) Fr., which developed on deer dung from Effingham County, appears to be the first record of this species on dung for the United States.

Several coprophilous pyrenomycetes, three of which may be found on substrata other than dung, have been reported from Illinois. Cain and Groves (1948) found *Podospora inaequalis* (Cain) Cain on seeds from Illinois. Skolko and Groves (1953), in examining the collections of Chivers, reported Illinois material of *Chaetomium globosum* Kunze on corn husks and of *Chaetomium murorum* Corda on a culture of chips. Cain (Cooke, 1969) reported the following coprophilous species from the 1965 Illinois foray: *Bombardia coprophila* (Fries), *Podospora anserina* (Ces.) Winter, *Podospora coronifera* (Grove) Cain, *Podospora fimicola* Ces., *Podospora vestita* (Zopf) Winter, and *Zygopleurage zygospora* (Speg.) Boedijn. All other species listed below are thought to be reported for the first time from Illinois.

SPECIES LIST

Chaetomiales
Chaetomiaceae
Chaetomium aterrimum Ellis and Everhart (1) GU
Chaetomium bostrychodes Zopf (13) D, H, RA, SQ, R
Chaetomium caprinum Bainier (3) D, H, R
Chaetomium cochliodes Palliser (2) C, H
Chaetomium crispatum Fuckel (2) R, C
Chaetomium globosum Kunze (5) H, R, SQ
Chaetomium funicolum Cooke (1) H
Chaetomium murorum Corda (7) C, D, G, H, S, TR
Chaetomium seminudum Ames (1) R
Sphaeriales
Sordariaceae
Bombardia coprophila (Fries) Kirsch. (1) C
Coniochaeta Hansenii (Oud.) Cain (1) R
Coniochaeta scatigena (Berk. and Broome) Cain*
Phomatospora hyalina (Griff.) Cain (1) C
Podospora aloides (Fuckel) Mirza and Cain (1) C
Podospora anserina (Ces. ex Rabenh.) Niessl (9) G, H, S, TR
Podospora appendiculata (Auersw.) Niessl (3) R
Podospora australis (Speg.) Niessl (1) H
Podospora communis (Speg.) Niessl (7) H, S
Podospora curvicolla (Winter) Niessl (22) H, R
Podospora curvula (DeBary) Niessl (7) C, H
Podospora dakotensis (Griff.) Mirza and Cain (1) R
Podospora decipiens (Winter) Niessl (5) C, H
Podospora fimicola Ces.*
Podospora inaequalis (Cain) Cain (1) H
Podospora pleiospora (Winter) Niessl (3) H, R
Podospora pyriformis (Bayer) Cain*
Podospora setosa (Winter) Niessl (1) R
Podospora similis (Hansen) Niessl*
Podospora tetraspora (Winter) Cain (11) RA, R
Podospora vesticola (Berk. and Broome) Mirza and Cain (12) C, G, H, S
Sordaria fimicola (Rob.) Ces. and De-Not. (13) C, D, H, R
Sordaria humana (Fuckel) Winter (5) D, G, R, TR
Sordaria zygospora Speg.*
Hypocreales
Nectriaceae
Nectria coccinea (Pers. ex Hook.) Fr. (1)

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THE MICROENVIRONMENT OF *CLIMACIUM AMERICANUM*

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ABSTRACT.—Maximum and minimum temperatures and relative humidity of the air at one cm above the soil surface, soil temperature, potential evaporation rate, soil moisture and organic matter present in the soil were measured for five plots that appeared to be very similar habitat types. The plots on which *C. americanum* occur were found to have relatively low maximum and minimum temperatures, high relative humidity of the air layer directly over the plots, relatively low rates of potential evaporation, relatively low soil temperatures, and soils that are moderately acidic. Each of the plots on which *C. americanum* does not occur was found to be notably different in terms of one or more of the environmental factors measured than the plots where *C. americanum* is present.

Climacium americanum Brid. is a distinctive yellow to green pleurocarpic moss with prostrate underground stems. The plants are approximately 3 to 5 cm tall with many erect stems, each bearing numerous spreading branches at the tips.

The purpose of this study is to determine the environmental factors that limit the distribution of the bryophyte *C. americanum.*

This particular moss was chosen for the study because it was found to occur only on soil in dense mats, in very moist, well-shaded and litter-free areas; at or slightly below the crests of northfacing slopes. This restrictive habitat suggested to the investigators that the occurrence of this bryophyte depends on some very exacting environmental requirements. Due to their small size, bryophytes are ideal subjects for microclimatic studies. Most ecological studies on the bryophytes have emphasized the role of moisture in determining suitable habitats. Billings and Anderson (1966), and Potzoer (1939) found that the presence of certain bryophytes in a given habitat is a reliable indicator of the availability of moisture in that habitat. Moisture gradients have been found in vegetative continuums of bryophyte species (Foote, 1966). Moisture in the form of atmospheric humidity and rainfall was found to be a very important factor in governing the geographic distribution of many species of bryophytes (Tallis, 1958). The importance of substrata and soil conditions in governing the distribution of many bryophyte species was shown by Glenn and Welch (1931). Miyata and Hosokawa (1961) found that light interacts with atmospheric humidity in limiting the distribution of certain mosses that occur on tree trunks.

Materials and Methods

The study area, Lake Argyle State Park, is located approximately five miles west of Macomb, Illinois in McDonough county. It occupies the following portions of three townships: Colchester township; the northeast one fourth of section 1, R4W, T5N, and the northwest one fourth of section 6, R3W, T5N; Emmet township; the southwest one third of section 31, R3W, T6N; and Hire township; the southeast one third of section 36, R4W, T6N.

The study area consists of 1056 acres, of which 95.1 acres are occupied by an artificial lake (Dunn, 1968). Prior to its acquisition for a state park, the area had been disturbed by heavy pasturing, and the

timber areas cut over (Myers and Wright, 1948). The use of the park for public recreational purposes has caused a great deal of disturbance in certain areas.

The topography of the area is generally rough, being dissected by numerous ravines. The soil of the area is a Clinton Silt Loam (Fehrenbacker et al, 1967).

The temperate climate of the area has a very wide temperature range from minus 36° C to over 38° C. January is usually the coldest month, and July is normally the hottest month. The average annual precipitation is about 90 cm, and approximately 66 percent of this falls during the average growing season of 174 days. The summer season frequently has periods of high humidity (Dunn, 1968).

Microclimatic studies on *Climacium americanum* were initiated April 9, 1969, shortly after the soil on the north-facing slopes had thawed. The study was originally intended to be terminated after the onset of frost in the fall, but the advent of open hunting in the study area made it too risky to leave equipment out overnight, so the investigation was terminated on September 30, 1969.

Five plots for collecting data were selected in this study. Plots number 1 and 4 were chosen because *C. americanum* was abundant on these sites. Plots 2, 3, and 5 were chosen because their habitats appeared to be ecologically similar to plots 1 and 4; however, *C. americanum* was absent in these latter habitats.

Plot 1 is located on the crest of a north-facing slope. Red oak (*Quercus rubra* L.) and black oak (*Quercus velutina* lam.) trees, and many Americanum elm (*Ulmus americanum* L.) saplings provide shade. *Climacium americanum* grows on the crest of the north-facing slope in such a position that the upper portion of the mat begins where the slope has an angle of 16½ degrees. The lower portion of the mat is located where the slope has an angle of 34½ degrees, and below the mat the angle of slope is 42 degrees. The *C. americanum* mat covers an area of approximately two by four meters; however, it is also present in numerous other places along the same slope. The mat is growing upon a mineral soil approximately three cm in thickness that overlies a layer of sandstone. Very little litter is present on this portion of the slope, and there is negligible invasion of the mat by herbaceous species during any part of the growing season. *Thuidium recognitum* (Hedw.) Lindb. and *Bartramia pomiformis* Hedw. are two species of mosses that occur on this slope in abundance. They frequently grow adjacent to the mats of *C. americanum* but rarely seem to invade them.

Plot 2 is located about 10 meters above the crest of the same north-facing slope where plot 1 is located. The angle of slope at this point is 14 degrees. *Climacium americanum* does not grow this far above the crest of the slope. This plot is not as well shaded as plot 1, but it has a fairly closed canopy of black oak and shagbark hickory (*Carya ovata* (Mill.) K. Kock) trees. It receives additional shade from the numerous small American elm trees and saplings, and from several black oak saplings. The mineral soil on plot 2 is much thicker than it is on plot 1, and a sparse litter layer is also present. A relatively abundant growth of grasses does occur on plot 2, but mosses are not present on the soil in this region.

Plot 3 is located at the base of the same north-facing slope on which plots 1 and 2 are located. *Climacium*

americanum does not grow at the base of this slope. The angle of slope where plot 3 is located is two and one half degrees while above plot 3, the slope is 39 degrees. Dense shade is afforded plot 3 by the north-facing slope above it, several large black oak trees, several large hickory trees (*Carya cordiformis* (Wang.) K. Koch); and American elm saplings. The mineral soil varies from complete absence to several cm of thickness and is covered by a thin litter layer. Vascular plants and mosses are absent from plot 3.

Plot 4 is located just below the crest of a north-northeast facing slope. *Climacium americanum* is present on plot 4 in a mat of about four by four meters, and the angle of slope at this point is 28 degrees. Shade is afforded the mat by several black oak and sugar maple (*Acer saccharum* Marsh.) trees, and saplings of these species. There is almost no litter present on this portion of the slope, and the mineral soil is at least 15 cm thick. Another moss, *Thuidium recognitum*, is common on this portion of the slope. There is no apparent invasion of the *C. americanum* mat by herbaceous plant species, or *Thuidium recognitum*.

Plot 5 is located just above the crest of a north-northwest facing cliff. The slope in the region of plot 5 is 26 degrees. Shade is afforded the site by black oak trees and several species of oak (*Q. velutina, Q. palustria* Muench., and *Q. imbricaria* Michx.) and American elm saplings. This is the least shaded of the 5 plots studied. Although C. *americanum* is not present on this slope, the mosses *Thuidium recognitum* and *Bartramia pomiformis* form large mats on the soil in this habitat, and small herbaceous plants are present. There is almost no litter layer on plot 5, and the mineral soil is over 15 cm thick.

Maximum-minimum temperature, relative humidity of the air at one cm above the mat surface, soil temperature, potential evaporation, soil pH, soil moisture, and organic matter present in the soil were recorded for each of the five plots.

Microclimatic data were collected four days each week, Monday through Thursday. Care was taken to collect data at approximately the same time each day. Data were recorded on each of the five plots from the initiation of the study on April 19, 1969 until May 8, 1969. On May 9, the equipment on plots 1 and 2 disappeared, so the collection of data from these two sites had to be abandoned. On May 17, 1969 the maximum-minimum thermometer on plot 3 was found to be broken and could not be replaced. From May 17, 1969 through the termination of the study, all categories of data were taken on plots 4 and 5, and all data excepting maximum-minimum temperature were taken on plot 3.

From April 9, 1969, until April 30, 1969, maximum-minimum thermometers were placed on each plot on Mondays, the first day of each week for collecting data. On the next day, the maximum-minimum temperatures were recorded, and the thermometers were taken back to the lab. On Wednesdays, they were reset and placed on the plots to be read again the following day. This allowed two readings for maximum-minimum temperature per week. From April 30, until the termination of the study, the maximum-minimum thermometers were placed on the plots on Mondays, and readings were taken on Tuesdays, Wednesdays, and Thursdays. This allowed three readings per week.

Soil temperatures were recorded at each plot with an Atkins Ther-

mister, model number 3fo1A-F. Readings were obtained with a soil probe that was inserted into the soil, to a depth of one half cm; therefore the soil temperature readings were composite temperatures of the first one half cm of the soil. Four readings per week for each plot visited were obtained with this instrument.

Relative humidity readings were obtained with an aspirated psychrometer. Air for the measurement was taken at about one cm. above the soil surface. Four readings a week for each plot were obtained.

Potential evaporation, or the drying power of the atmosphere, was measured with standardized Bellani plates. On the first day for collecting data of each week, the Bellani plates were placed in holes deep enough to allow the evaporation surfaces to be nearly level and parallel with the soil surface. The volume of water lost from each apparatus was recorded on the following day. They were then taken back to the lab, stored in a container of deionized water, refilled, and placed on the plots again on Wednesday, the third day for collecting data of each week. On the fourth day, the final weekly reading was recorded. This allowed two readings for potential evaporation per week. Care was taken not to leave the plates out for more than one day at a time. This precaution was taken in order to keep the evaporation surfaces as clean as possible. The plates were checked twice during the study to see if restandardization was necessary. The Bellani plates were not put out on rainy days, because exposure to this type of weather can result in a growth of algae on the evaporation surfaces.

The soils of each site were tested as to pH, soil moisture, and the amount of organic matter present. The pH was determined with the use of a soil testing kit. The soil moisture was computed by drying the samples in an oven at approximately 120° C, and organic matter present was determined by ashing the samples.

The data from each plot were statistically analysed. The data in each category (relative humidity, soil temperature, etc.) were sorted as to the type of weather that prevailed on the day each reading was taken. An F test was made on each data grouping. For groups showing a significant F value, Duncans new multiple range test was run. This is a comparison of each treatment mean (mean for one plot) with each other treatment mean.

RESULTS AND DISCUSSION

Data collected in this investigation were separated into several groups before they could be analysed. These groupings are as follows: (1) that recorded from plots 1 through 5, (2) that recorded from plots 3 through 5 only, and (3) that recorded from plots 4 and 5 only (maximum and minimum temperature values only). Each of these groups was broken down into categories corresponding to the type of weather present on the date that each reading was recorded.

Significant differences or statistical separations mentioned in the following discussion refer to the 95 percent level of significance.

Maximum temperature. Maximum temperature data collected from plots 1 through 5, 3 through 5, and plots 4 and 5 were analysed in the following categories: (1) all days, (2) all sunny days, (3) all cloudy days, and (4) all partly cloudy days on which data were recorded.

Plots 1 and 4 (on which *C. americanum* occur) have significantly lower mean values for maximum temperature than plots 5 and 2 on

data in the all days grouping. Plots 1, 3, and 4 have significantly lower mean values than plot 5, and plots 3 and 4 have significantly lower mean values than plot 2 for maximum temperature data collected on sunny days. Data collected on cloudy days shows plots 1 and 5 (with the lower mean values) separating statistically from plot 2.

Differences among maximum temperatures for plots 3 through 5 were found only for cloudy days. Plot 4 has a significantly lower mean temperature than plots 3 and 5.

When plot 4 (*C. americanum* present) is compared with plot 5 for the entire study period, a significantly lower mean maximum temperature is found for plot 4 for the all days and all sunny days categories.

The results of the maximum temperature study show that plots 1 and 4 (where *C. americanum* occurs) generally have significantly lower maximum temperatures than plots 2 and 5 where the moss does not occur. Plot 3 generally has a maximum temperature near that of the cooler plots 1 and 4.

Minimum temperature. Minimum temperature data for plots 1 through 5, 3 through 5, and 4 and 5 only were separated into the following weather categories: (1) all days on which data were recorded, (2) all sunny days, (3) all cloudy days, and (4) all partly cloudy days.

Plot 2(*C. americanum* absent) is significantly warmer than plots 1, 3, and 5 on cloudy days, while plot 5 is significantly warmer than all other plots on sunny days. On all days that minimum temperatures were recorded for plots 1 through 5, plot 5 is significantly warmer than plots 1, 3, and 4; while plot 2 is significantly warmer than plots 1, and 3.

Statistical analysis of the minimum temperatures recorded for plots 3 through 5 indicates a difference for data recorded only on sunny days. In this category plot 5 is found to be significantly warmer than plot 3.

No significant differences are found for data concerning plots 4 and 5 only.

The results of the studies on minimum temperature indicate that the plots on which *C. americanum* occur (1 and 4) have significantly lower minimum temperatures than plots 5 and 2. Plot 3, on which *C. americanum* is not present, generally has minimum temperature values near those of the cooler plots (1 and 4).

Relative humidity. Relative humidity data from plots 1 through 5, and plots 3 through 5 only were separated into the following weather categories: (1) all days on which data were recorded, (2) all sunny days, (3) all cloudy days, (4) all partly cloudy days, (5) all rainy days, and (6) all nonrainy days.

A significant difference among plots 1 through 5 is found for all days, all nonrainy days, and all sunny days on which this data were collected. Plot 5, with consistently lower mean values for relative humidity, separates statistically from plots 1, 2, and 4.

A statistical separation among plots 3 through 5 is found for all days, all nonrainy days, all partly cloudy days, and all sunny days on which relative humidity data were collected. Plot 5, with consistently lower mean values for relative humidity is significantly different than plots 3 and 4 in each of the above mentioned weather categores.

Plot 5 is a different type of habitat than plots 1 through 4 in terms of relative humidity. Plots 1 and 4, on

which *C. americanum* occurs, do not separate statistically from plots 2 and 3 where this moss is absent; but it is evident that the plots on which *C. americanum* occur have comparatively high relative humidity values

Potential evaporation. Potential evaporation data from plots 1 through 5, and from plots 3 through 5 were separated into the same six weather categories as the relative humidity data.

Plot 1 is found to have a significantly lower potential evaporation rate than plots 2, 3, and 5 for the data collected on all days, and plot 1 is also found to have a significantly lower rate of potential evaporation than plots 2 and 5 for data collected on nonrainy days.

A statistical separation of plot 4 from plots 3 and 5 is found for data collected from plots 3 through 5 only on partly cloudy, sunny, nonrainy, and all days on which this data were collected. In each above mentioned category, plot 4 has a significantly lower potential evaporation rate than plots 3 and 5.

The results show that the plots where *C. americanum* occurs (1 and 4), are more protected or have lower rates of potential evaporation than the plots where it does not occur.

Soil temperature. The soil temperature data for plots 1 through 5 and plots 3 through 5 were separated into the same six weather categories as the relative humidity data.

No significant differences are found for soil temperatures recorded from plots 1 through 5. This is unexpected when compared to the data for plots 3 through 5, where plot 5 has significantly higher soil temperatures than plots 3 and 4 in the cloudy weather category, and each plot is significantly different in terms of soil temperature than the other plots for sunny, nonrainy, and all days on which this data were taken. In the last three weather categories mentioned, plot 4 has the lowest mean values for soil temperature while plot 5 consistently has the highest mean values.

Plot 1 has mean values for soil temperature that are approximately as low as those found for plot 4 in the data from plots 3 through 5, but significant differences are not found in data concerning plots 1 through 5. The reason for this may be that there are fewer samples of data to work with for plots 1 through 5 than for plots 3 through 5. It may be seen, however, that plots 1 and 4, on which *C. americanum* occur, have relatively low soil temperatures when compared to plots 2, 3, and 5.

Soil pH. A statistical analysis of the soil pH for plots 1 through 5 was not possible since only one sample was taken. A statistical analysis was made on data collected from plots 3 through 5, and each plot is found to be significantly different than each other plot. The soils on plots 1 (pH of 5.75) and 4 (pH of 5.40, a mean value) on which *C. americanum* occur, are more acid than that of plots 2 and 3 (each with a pH value of 6.50). Plot 5, with a mean pH value of 4.88, has the most acidic soil of any plot studied.

Soil moisture. No significant differences among the plots were found for soil moisture data. Some of the soil samples were taken when the soil moisture was near field capacity, and others were taken when the soil was relatively dry. It is expected that the similar habitats would have proportionate values for soil moisture in dry times as well as moist times, but no reliable trends toward grouping the plots on the basis of soil moisture are found.

Organic matter. The results of the studies on the organic matter pre-

sent in the soil of the plots show no significant differences among the plots.

Stability of mats. Observations during the study indicated to the investigators that the mats of *C. americanum* on plots 1 and 4 were expanding rather than being invaded by adjacent moss mats or by vascular plants.

CONCLUSIONS

The results of the microclimatic studies on *C. americanum* are summarized in Table I.

Plots 1 and 4, where *C. americanum* occur, are found to be similar for all types of data recorded. Both plots have relatively low maximum and minimum temperatures, high relative humidity of the air layer directly over the plots, relatively low rates of potential evaporation, relatively low soil temperatures, and soils that are moderately acidic. The apparently expanding nature of the *C. americanum* mats on plots 1 and 4, and the lack of invasion of these mats by adjacent moss species and vascular plants indicates that these habitats are well suited for the growth of *C. americanum.*

Plot 5 is a different type of habitat than plots 1 and 4 in that it has notably higher maximum and minimum air temperatures, higher soil temperatures, lower relative humidity, a higher rate of potential evaporation, and a more acidic soil.

Plot 3 is found to be a different type of habitat than plots 1 and 4 only in its higher rate of potential evaporation, somewhat higher soil temperatures, and almost neutral soil pH.

Plot 2 is found to be different than plots 1 and 4 in its higher maximum and minimum air temperatures, higher soil temperatures, higher potential evaporation rates, and almost neutral soil pH.

A set of environmental factors that limit the distribution of *C. americanum* are not positively found in this study. Therefore, the results of this investigation are not definitive. However, the high levels of significance found for potential evaporation, soil pH, maximum and minimum temperature, and soil temperature are strong indications that these could be limiting environmental factors concerning the distribution of this bryophyte. More data is necessary before the actual limits imposed on the distribution of *C. americanum* by these environmental factors can be determined.

TABLE I. Summary of Microclimatic Data.

Plot	Maximum temp.[1]	Minimum temp.	Relative humidity	Potential evaporation	Soil temp	pH
*1	Low	Low	High	Low	Low	Acid
2	High	High	High	High	High	Neut.[2]
3	Low	Low	High	High	Inter.[3]	Neut.
*4	Low	Low	High	Low	Low	Acid
5	High	High	Low	High	High	Very acid

* plots where *C. americanum* is present.
1 temperature
2 neutral
3 intermediate

Two other variables that may be of significance in limiting the distribution of *C. americanum* are the amount of shading afforded a particular habitat, and the relative amount of litter present. Both plots on which *C. americanum* occurred were well shaded and almost completely devoid of any litter layer.

The results of this investigation also indicate that unsuitable habitats may fail to meet environmental requirements for a particular species during certain types of weather only, or during certain portions only of the growing season.

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AN EVALUATION OF WATER QUALITY INFORMATION: A CASE STUDY OF STREAMS IN METROPOLITAN NEW JERSEY

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ABSTRACT.—Some of the best water quality data sets available in New Jersey are routinely collected by large public potable water supply agencies. One such set consisted of eleven variables (temperature, dissolved oxygen, turbidity, color, discharge, percent saturation, hardness, alkalinity, BOD, pH, and bacteria) collected every week at three sites in the Raritan River Basin. Factor analysis using the Varimax rotation resulted in three factors: an oxygen-related factor (high inverse loadings on dissolved oxygen and temperature), an appearance factor (turbidity, color and discharge), and a third variable factor occasionally loading on percent saturation. The cumulative percentage explained by the rotated factors declined during the decade, suggesting an increase in independence developing among the variables. It is hypothesized that urbanization with its commensurate changes in land use and runoff patterns might be intervening in the natural ecology of the stream. The effects of urbanization, then, would be to interfere with in-stream interaction among the variables. Factor structures were quantitatively compared from year to year and from site to site by a computer program called RELATE.

The purpose of this study is to evaluate the available water quality data in metropolitan New Jersey by the application of a factor analytic methodology. The decade of the 1960's was selected, as it included the continuation of urbanization with its resultant impact on watershed quality and periodic events such as the record drought of 1962-66. It was hoped that the relative effects of these trends and events could be isolated by factor analysis.

Factor analysis is one form of multivariate analysis wherein a set of intercorrelated variables is collapsed to form a smaller number of composite variables, or factors (King, 1969; Rummel, 1970). These are then rotated to yield a set of independent, uncorrelated factors.

Numerous investigators in a variety of disciplines have used factor analysis in their studies. For example, Weaver (1954) studied crop-combination patterns in the Midwest, using 88 counties and seven variables. Carey (1966) offered an interesting interpretation of the housing patterns of the population in Manhattan, based upon 33 socio-economic variables and 269 census tracts.

In the field of hydrology, Wong (1963) used a modified principal components analysis on 12 variables and 90 basins in New England in order to estimate the magnitude of the mean annual flood. Wallis (1965) used factor analysis in a study of the agents that contribute to soil erosion and stream sedimen-

tation in northern California. Dawdy and Feth (1967) applied factor analysis to results of chemical analyses of ground water samples from the Mojave valley in California. Matalas and Reiher (1967) felt that factor analysis was technically underdeveloped, a view seconded by Wallis (1968) who also felt, however, that the technique was a powerful tool for screening variables. Rice (1967) suggested Varimax rotation as an aid in rationally interpreting factors resulting from a study of hydrologic relationships. Eiselstein (1967) used a principal component regression analysis with Varimax rotation of the factor weight matrix as a means of synthesizing flow records for small ungaged watersheds. Annual precipitation and runoff data from 14 watersheds in Ohio and 7 watersheds in Texas were subjected to principal component and factor analysis by Diaz, Sewell, and Shelton (1968) in an attempt to identify the factors affecting the water yield of the basins. Knisel (1970) used factor analysis on 13 variables for five reservoirs in Texas to determine which variables were significant for estimating reservoir losses on the fissured limestone terrain.

METHODOLOGY

The factor analyses discussed in this paper were predicated on a number of conservative assumptions. First, the communality was estimated by using the square of the multiple correlation coefficient between each variable and all other variables in the data set. These communalities would appear along the principal diagonal of the correlation matrix.

Alternative estimates of the communality could have been chosen; for example, ones could be inserted in the principal diagonal. This procedure then assumes that all of the variance of each variable is related to the common factors of the data set. The true communality presumably lies between the R^2 and unity estimates; thus, the R^2 estimate is probably more realistic.

Secondly, the general factor analysis program used (BMD 03M) extracts a set of factors by the principal components method. These factors were then rotated so as to concentrate the loadings on a few of the factors. The rotation used was the Varimax solution, which involves a series of orthogonal transformations of factor pairs. The Varimax routine is perhaps the most commonly used form of rotation.

Rotations were performed on factors only if the eigenvalues exceeded unity. In almost all cases, this arbitrary but conservative rule ensured that all factors accounted for at least as much as one of the original variables. In order to ensure uniformity among factor structures on some data sets, some factor analyses were repeated with a stipulated but reasonable number of factors to be rotated.

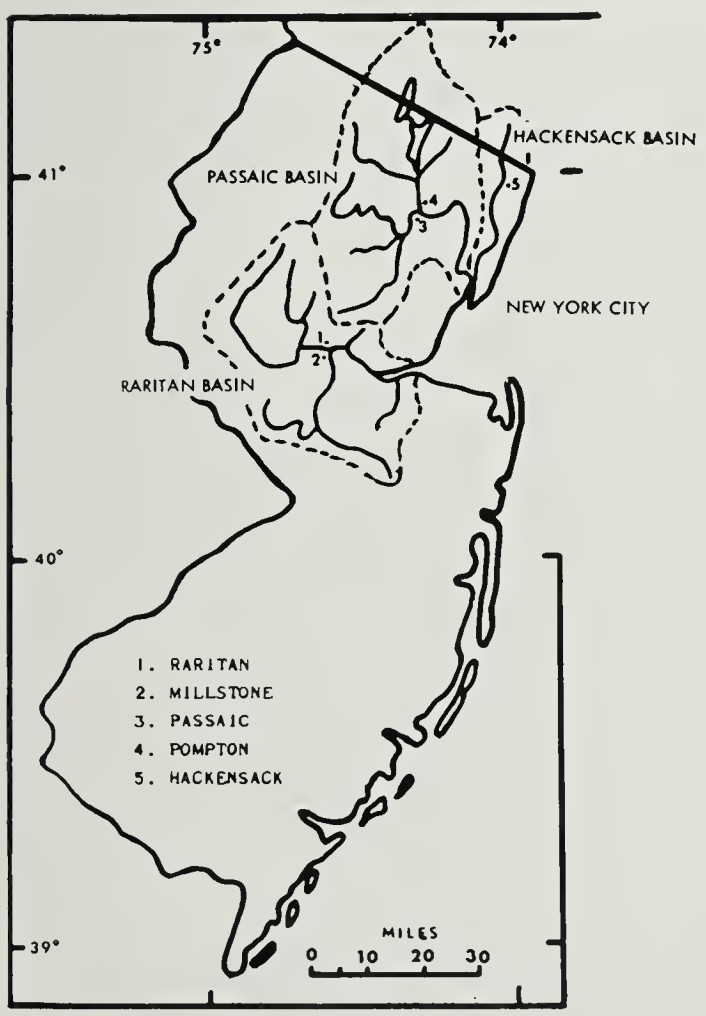
Quantitative factor structure comparisons can be achieved by using a computer program called RELATE. As discussed by Veldman (1967) this program accepts as input the factor loading matrices that were obtained from an orthogonal factor analysis of identical sets of variables. Then the factor axes are rotated until maximum overlap between corresponding test vectors in the two structures is attained. The degree of rotation required is expressed as the cosine of the angle between the factor axes. These cosines may be interpreted as correlations between the factor variables.

Acquisition of the requisite water quality data sets was an immediate and troublesome task. Preliminary investigation revealed sampling in-

adequacies in frequency, duration, and number of variables. Data storage and retrieval problems were also evident. From the mix of public and private agencies that operate stream sampling stations in New Jersey, it was determined that some of the best sets of water quality information were routinely collected by large potable water supply agencies.

Fortunately, an excellent set of data for the Raritan Basin was available in the files of the Elizabethtown Water Company (EWC), one of the largest private water purveyors in the country. In 1971, EWC distributed 117 mgd (441,090 m^3/day) to 44 municipalities in central New Jersey (EWC Annual Report, 1971). Most of the water (about 75%) is diverted from the Raritan and Millstone Rivers near Bound Brook (see Figs. 1 and 2) and the Delaware-Raritan Canal which flows parallel to the Millstone.

2. Schematic Map of the Raritan River Basin.



1. Major Watersheds in Northeastern New Jersey.

EWC samples its raw water on a daily, weekly, and monthly basis for 6, 9, and 17 variables, respectively, for each of the three intakes near the filter plant. With the addition of discharge and percent saturation, the best mix of frequency of observation and total number of variables is attained with the weekly series.

The Raritan River Basin is one of the largest in New Jersey, covering 1,100 square miles (2849 sq. km.). The Raritan River rises in the Highlands of New Jersey and then flows eastward through the Piedmont Province. The total length of the Raritan is over 74 miles (119 km.), with the tidal portion accounting for 19 miles (31 km.) or 26%. The drainage area just above the confluence with the Millstone River is 490 square miles (1269 sq. km.). The average discharge for 52 years of record is 716 cfs (20.3m^3/sec.), or 1.46 cfs/square mile (0.016 m^3/km^2).

The Millstone River rises in the Coastal Plain Province, flows westward and then northward through the Piedmont Province where it joins the Raritan near Bound Brook (see Fig. 2). The drainage area is over 260 square miles (673 sq. km.) with a main channel length of 28 miles (45 km.). The average discharge for 49 years of record is 356 cfs (10.1 m^3/sec.), or 1.38 cfs/square mile (0.015 m^3/km^2).

Following adjacent to the Millstone and then the Raritan River is the Delaware-Raritan Canal. By virtue of a U.S. Supreme Court decision in 1954, New Jersey can divert up to 100 mgd (377,000 m^3/day) of raw water from the Delaware River at Raven Rock, about 20 miles (32 km.) upstream of Trenton (New Jersey, Commission on Efficiency, 1967). The water then flows by gravity through the 55-mile (88 km.) long canal until it empties into the tidal Raritan at New Brunswick. Consequently, Canal water comes from a basin of approximately 6,350 square miles (16,447 sq. km.), about 13 and 24 times larger than the gaged portions of the Raritan and Millstone basins, respectively.

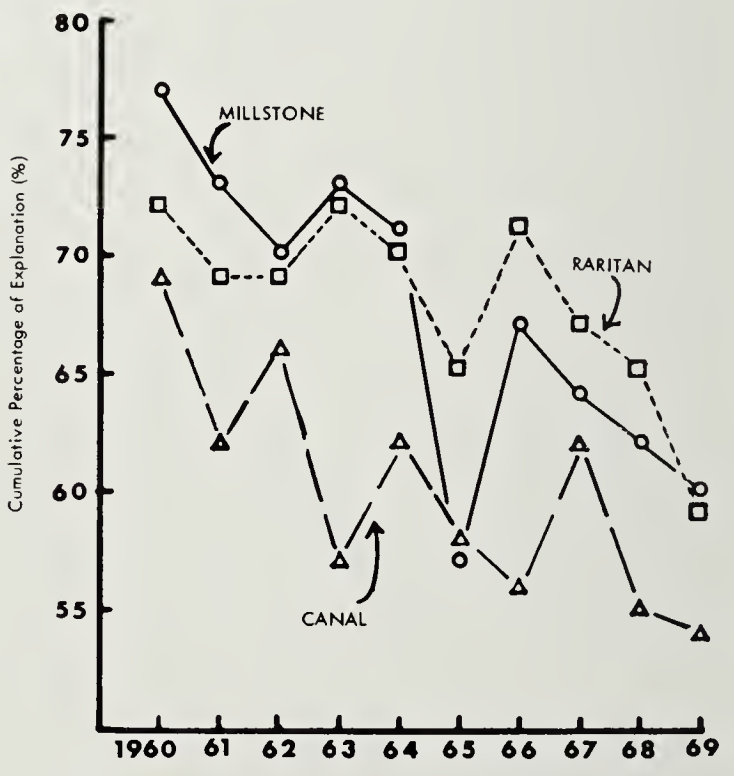
Analysis of the Data

Eleven variables were available at each of the three EWC stations: temperature, pH, DO, turbidity, BOD, color, alkalinity, hardness, bacteria, discharge, and percent saturation. The ten years of weekly observations comprise 5,720 bits of information at each site, or over 17,000 bits for the three sites. The data were arranged in calendar year sets.

The first run of factor analyses resulted in structures about evenly divided between two and three factors. In order to preserve year to year consistency in interpretation, the data were factor analyzed again, this time specifying that three factors were to be rotated. The following discussion is based on the ordered three factor runs.

The cumulative percentage of explanation of the rotated factors is plotted in Figure 3. The Millstone decreases from a peak of 77% in 1960 to a low of 57% in 1965, averaging 67% for the decade. The Canal structures yield the lowest percentages of explanation, ranging from 69% in 1960 to 54% in 1969, averaging 60% for the decade. Although the decline is not steady from year to year, a pronounced secular decrease in explanation is apparent for all three intakes. This decline suggests an interference in in-stream interactions among the variables. It is hypothesized that human interference might be the causative agent, in the form of increased effluent discharges and accelerated runoff commensurate with urbanization and land use changes.

The rotated factor loadings for selected years are shown in Table 1. For clarity, only the highest loading for each variable is shown. Thus, a



3. Cumulative Percentage of Explanation of the Rotated Factors, Elizabethtown Water Company.

TABLE 1.—*Rotated Factor Loadings for Selected Years of the Elizabethtown Water Company Data*

Intake	Factor	Percent[1] Expl.	Temp.[2]	DO	BOD	pH	Alk.[3]	Q[4]	Turb.[5]	Color	Hard.[6]	Percent[7] Sat.	Bact.[8]
Canal	1	30	—.92	.85	.76			—.69			.72		
1960	2	24				.64	.76		—.77	—.80			
	3	15										.94	—.31
	All	69											
Canal	1	23	—.93	.86	.70								
1969	2	16				.55	.61		—.64	—.67	.39		
	3	15						—.45			—.37	.94	—.38
	All	54											
Millstone	1	34	—.93	.99	.69		—.67					.84	
1960	2	31						.80	.97	.96			.75
	3	12				.64					.59		
	All	77											
Millstone	1	24		.87	.74							.97	
1965	2	21	—.81			—.58	—.62	.51					—.64
	3	12							.73	.66	—.27		
	All	57											
Raritan	1	29	—.93	.85	.69	—.55	—.58						
1960	2	28						.75	.89	.94			.61
	3	15									.56	—.82	
	All	72											
Raritan	1	24	—.94	.94	.74	.46	.52						—.25
1969	2	24						—.88	—.78	—.81			
	3	11									.37	—.91	
	All	59											

Notes:
[1] Percent Expl.—Percent Explanation
[2] Temp.—Water Temperature
[3] Alk.—Alkalinity
[4] Q—Discharge
[5] Turb.—Turbidity
[6] Hard.—Hardness
[7] Percent Sat.—Percent Saturation
[8] Bact.—Bacteria

blank indicates a factor loading less than .70, a conservative threshold for significance. The remaining 24 factor structures that are not shown in Table 1 are broadly similar to the six representative structures. The similarities and differences between and among the entire 30 factor structures will be discussed in a later section.

The factor structures generally reveal the following characteristic pattern: (1) an oxygen-status factor, represented by high loadings on temperature, DO, and BOD; (2) an appearance factor based on turbidity, color, and discharge; and (3) a third variable factor, loading occasionally on percent saturation.

The oxygen-status factor tends to be the component of greatest statistical importance. Temperature and DO almost always have the highest loadings in the factor matrix, usually about .9. The loadings are inversely related, which is in accord with the temperature-DO relationship. Note in Table 1 that in 1965 on the Millstone this relationship is severed, as temperature and DO split their association between two factors. Presumably, this anomaly was caused by drought conditions, as 1965 was the driest year in the 1962-66 drought. Although not shown in Table 1, temperature and DO were also separated in 1965 for the Canal.

The second most important factor in terms of explanation is one based on appearance, *i.e.,* high loadings on turbidity, color, and occasionally discharge. Note that bacteria forms some association with the factor in 1960 for the Millstone and Raritan.

High loadings on percent saturation occasionally form a separate third factor. This last factor generally offers only half the explanation of the first factor.

Bacteria, hardness, pH, and alkalinity generally exhibit the lowest loadings of any of the 11 variables. Indeed, bacteria is the least related to any of the other variables in the data set.

Factor Structure Comparisons

In order to assess inter-basin and inter-basin changes in watershed characteristics, the EWC factor structures were compared in space and over time. As mentioned previously, the computer program RELATE (Veldman, 1967) quantitatively compares one factor structure with another as long as the variables are the same and remain in identical order.

RELATE enables one to indicate the degree of similarity between factor structures by obtaining the cosine of the angle between component vectors. These cosine values may then be interpreted as correlation coefficients. Perfect identity in the comparisons would be denoted by an identity matrix I with ones in the principal diagonal. Hughes (1971) used RELATE in his study of major urban metropolitan systems. As Hughes states, "The greater the value of the off diagonal, the greater the difference between the corresponding factors."

The following three examples should clarify the discussion. Consider the following three matrices:

		System B		
I. System A	1	0	0
	0	1	0
	0	0	1

		System B		
II. System A	0	1	0
	1	0	0
	0	.0	1

		System B		
III. System A	.80	.05	.60
	.05	.99	.01
	.60	.02	.80

A perfect identity is indicated in example I. The first factor in A is identical to the first factor in B, the second factor in A is identical to the second factor in B, and so on.

Similar factor structures are shown in example II, but the individual factors vary in their importance within each system. Thus, the second factor in A is identical to the first factor in B, since a cosine of 1.0 indicates a zero degree angle between the cosines.

Dissimilar structures are indicated in example III, where the first and third factors of A and B are less than perfectly associated with a value of .80. Only the second factors of A and B with a cosine of .99 come very close to identity.

Summarizing, any value less than unity in the diagonal implies some difference between the corresponding structures.

The discussion in this section will focus on the comparison between factor structures for each intake from year to year and from intake to intake for the same year.

The Canal provides the best year to year comparisons. As shown in Table 2, the mean value for all years exceeds .80. Indeed, only once during the decade (1965-66) did the mean cosine fall as low as .81. For five of the nine years of comparison (1960-61, 1962-63, 1963-64, 1966-67, and 1967-68), the mean value was greater than or equal to .95. The grand mean for the decade was .93, exceeding the values of .91 and .87 for the Millstone and Raritan, respectively. Thus, the Canal provides the most consistent set of factor structures of the three intakes. This consistency is attributed to the regularity of the Canal discharge. Also, Canal water is coming from a large basin which tends to dampen water quality variation.

Conversely, the Raritan structures show the lowest year to year comparisons. Note the .71 and .79 values for 1960-61, and 1962-63 and 1967-68 (Table 2). Interestingly, the peak mean values of .99 for 1964-65 and 1965-66 contrast markedly with the same periods for the Canal, when decade minimums were reached. Pre-

TABLE 2

Intra-Basin Comparison: Mean Cosine Values of Factor Structures for Consecutive Years for Each Intake

Year	Mean Cosine Value		
	Canal	Millstone	Raritan
1960-61	.95	.89	.71
1961-62	.94	.80	.82
1962-63	.97	.89	.79
1963-64	.95	.97	.88
1964-65	.89	.94	.99
1965-66	.81	.84	.99
1966-67	.95	.94	.97
1967-68	.99	.95	.79
1968-69	.89	.99	.87
Decade Mean	.93	.91	.87

sumably, the flow augmentation on the Raritan accounts for the disparity between the two stations. The decade grand mean of .87 is the lowest of the EWC stations.

The Millstone values are intermediate among those of the Canal and Raritan. The lowest mean value of .80 was reached in 1961-62, whereas higher values were attained in the latter part of the decade. In three years out of the nine, mean values were equal to or greater than .95 (Table 2).

Summarizing, although there is some variation in year to year factor comparisons among the three sets, the dominant theme is one of factor stability over time. That is, the similarities from year to year are greater than the differences. Thus, the results from the structure comparison part of the RELATE program (cosine values) support the earlier findings of two or three characteristic water quality factors.

Turning now to inter-basin factor comparisons within the Raritan, we find in Table 3 that the Canal is structurally quite similar to the Millstone. This is surprising, inasmuch as Canal water is really Delaware River water which is coming from a basin about 24 times as large as the Millstone. The mean cosine value varies from a low of .75 in 1960 to a high of .99 in 1965, averaging .89 for the decade. There is noticeable fluctuation from year to year, but the associations remain strong.

Structural congruence between the Canal and Raritan exists, but at a lower level. For three years in the decade, the mean cosine value is less than or equal to .75. The overall decade mean drops to .84, as compared to .89 for the Canal and Millstone. Thus, we may conclude that even though the Canal water is coming from a different basin, the factor structures on the Canal are similar to those of the Millstone and Raritan.

As shown in Table 3, the factor structures between the Millstone and Raritan are strongly associated. In only one year (1967) did the mean cosine value drop as low as .75. For

TABLE 3

Inter-Basin Comparison: Mean Cosine Values for Paired Basins For Each Year

Year	Mean Cosine Value		
	Canal and Millstone	Canal and Raritan	Millstone and Raritan
1960	.75	.86	.91
1961	.98	.75	.92
1962	.87	.84	.94
1963	.80	.96	.81
1964	92	.70	.98
1965	.99	.95	.91
1966	.87	.92	.84
1967	.95	.78	.75
1968	.82	.68	.91
1969	.97	.92	.90
Decade Mean	.89	.84	.89

seven years out of the decade, the mean values were equal to or greater than .90. This structural similarity is to be expected, in view of the fact that both streams drain major sub-basins within the same watershed.

The test R portion of the RELATE program measures the degree of association between variables from year to year within a basin and from basin to basin for paired years. Briefly, the highest correlation coefficients are reported for temperature, DO, and percent saturation, whereas hardness, bacteria, and occasionally BOD represent the more erratic variables. Generally, most variables are highly consistent from year to year. A fuller discussion of the test R results is contained in the larger study of water quality in the New York Metropolitan Region by Carey, Zobler, Greenberg, and Hordon (1972).

In conclusion, the factor structures of the Canal show a surprising similarity to those of the Millstone during the decade of the 1960's. The Canal also displays a structural congruence to the Raritan, but to a lesser degree. As might be expected for sub-basins of a larger basin, the Raritan and Millstone are structurally similar. Thus, even though the decade of the 1960's included a record-breaking drought, the similarities among the factor structures over time and through space are greater than the differences.

APPLICATIONS

The techniques of factor analysis and RELATE may assist water resource managers in a variety of ways. For example, factor analysis may be used to develop a classification of watercourse types in a region. Such a typology may be based on characteristic factor structures resulting from differences in regularity of discharge, extent of impervious cover, geohydrologic controls, and watershed sensitivity to land use changes.

RELATE may be used to compare existing factor structures against hypothetical structures. The hypothetical or target structure would have factor loadings specified by the user. Indices of similarity or dissimilarity can be developed by comparing the desired or goal structure with the existing factor patterns. These procedures are referred to by Rummel (1970) as "target rotation analysis."

ACKNOWLEDGMENTS

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NEW PLANT RECORDS FOR ILLINOIS

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ABSTRACT.—Two cultivated taxa are reported for the first time as adventive in Illinois. These are the commonly cultivated shrub *Euonymus alatus* (Thunb.) Sieb. and the occasionally planted grass *Pennisetum alopecuroides* (L.) Spreng.

Efforts have been made during the last few years to make extensive plant collections from east-central Illinois. These efforts have resulted in range extensions for some species (Ebinger, 1967; Parker, Rayhill, and Ebinger, 1969), and recently, the addition of two adventive species to the Illinois flora. These two species with the collecting data and other pertinent information concerning habitat is listed below. Specimens of these taxa are deposited in the Stover Herbarium, Eastern Illinois University (EIU).

Euonymus alatus (Thunb.) Sieb. This taxon, a native to China and Japan, has been reported as rarely escaping from cultivation in eastern United States (Gleason, 1952). It is easily separated from the native *E. atropurpureus* Jacq. by the well developed corky wings on the branches, and the bright crimson autumn foliage which makes it a very desirable and commonly planted shrub. The population studied dominates the understory in the more shaded parts of an north facing hillside and valley floor, being particularly abundant in small ravines. The entire population extends over an area of about 4 acres with the overstory dominated by a mature oak, hickory, sugar maple forest. The understory also contains flowering dogwood, blue beech, ironwood, and bladdernut. Some of the *E. alatus* specimens are 15 feet tall, 2 inches in diameter (d.b.h.) and in excess of 25 years old. Numerous smaller plants and seedlings are also common. Coles County: wooded hillside ½ mile east of Charleston (NW¼, Sect. 24, R9E, T12N), 12 August 1971, *J. E. Ebinger* 10708 (EIU); 12 October 1972, *J. E. Ebinger 12215* (EIU, ILLS, ISM, SIU).

Pennisetum alopecuroides (L.) Spreng. This grass, which is native to China, is occasionally cultivated and apparently hardy in northeastern United States (Bailey, 1949). This member of the tribe Paniceae has spikelets with an involucre of numerous bristles, a characteristic also found in the genus *Setaria* Beauv. In *Pennisetum* L. Rich., however, the spikelets fall together with the involucre bristles while in *Setaria* the spikelets disarticulate above the persistent bristles (Gould, 1968). The population studied dominates along, and 20-to 30-feet on either side of a small stream in a heavily grazed pasture. The entire population consists of more than 1000 clumps each containing about 25 culms. The clumps nearest the stream are more than 2 feet tall while those further away become progressively smaller. Numerous other species are present with the most important being *Amaranthus spinosus* L., *Stellaria media* (L.) Vill., *Muhlenbergia schreberi* J. F. Gmel, *Digitaria ischaemum* (Schreb.) Muhl., *Trifolium pratense* L., *Polygonum aviculare* L., *P. persicaria* L., and *P. punctatum* Ell. Crawford County: open pasture 2 miles east of Oblong (NW¼, Sect. 33, R13W, T7N), 23 August 1971, *L. Phillippe 981* (US); 8 October 1972, *L. Phillippe 2188* (EIU, ILLS, ISM, RM, SIU).

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ADDITIONS TO THE FLORA OF COLES COUNTY, ILLINOIS

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ABSTRACT.—A total of 198 vascular plants are reported that have not been previously recorded for Coles County, Illinois.

The total reported vascular flora for Coles County, Illinois was 639 species according to the data compiled by Jones and Fuller (1955) and Winterringer and Evers (1960). In 1967, Ebinger reported the addition of 9 species of ferns and fern-allies and 80 species of monocots to the county. Later, in a floristic study of a series of hillside marshes, Parker, Rayhill, and Ebinger (1969) reported an additional 56 plant species to the Coles County flora.

Most of the species included in the present list are the result of extensive collections during the last ten years by the author and many of his students. Some of these collections, however, date from 1906. In particular, the collections by H. C. Sampson and P. Sargent are more than 60 years old. Many of the collections by these two collectors represent the only specimens of these species known from Coles County. Recent attempts to relocate these species have generally been unsuccessful, usually because the habitat has been destroyed.

Some of the species recorded are cultivated plants that are reproducing and are becoming a part of the county flora. Recently, Phillippe and Ebinger (1972) reported 5 cultivated shrubs that are found growing wild at Lincoln Log Cabin State Park while Ebinger and Phillippe (1974) reported *Euonymus alatus* (Thunb.) Sieb. as being adventive in Illinois.

The following list contains 198 species of vascular plants not previously recorded for Coles County. Each species is followed by the collectors last name and field number. All specimens are deposited in the Stover Herbarium of Eastern Illinois University. The nomenclature in the list follows that of Jones (1963).

DICOTYLEDONEAE

AMARANTHACEAE: *Acnida tamariscina* (Nutt.) Wood. Ebinger 7878. *Amaranthus albus* L. Ebinger 6767. *Amaranthus graecizans* L. Whiteside s.n. *Amaranthus hybridus* L. Tiffany s.n. *Amaranthus spinosus* L. Thut & Speer s.n. *Froelichia campestris* Small Thut, Stover, & Damann s.n.

ANACARDIACEAE: *Rhus typhina* L. Ebinger 4611.

APOCYNACEAE: *Apocynum androsaemifolium* L. Ebinger 4402. *Vinca minor* L. Ebinger 9393.

ARALIACEAE: *Aralia racemosa* L. Ebinger 11047.

ASCLEPIADACEAE: *Ampelamus albidus* (Nutt.) Britt. Ebinger 5831. *Asclepias exaltata* (L.) Muhl. Thut s.n.

BIGNONIACEAE: *Catalpa bignonioides* Walt. Ebinger 10434.

BORAGINACEAE: *Echium vulgare* L. McClain 265.

CAMPANULACEAE: *Campanula rapunculoides* L. Ebinger 7653.

CANNABINACEAE: *Cannabis sativa* L. Baumann 89. *Humulus americanus* Nutt. Ebinger 5788.

CAPPARIDACEAE: *Cleome speciosissima* Deppe Carbonari 181.

CAPRIFOLIACEAE: *Diervilla lonicera* Mill. Sampson 1802. *Lonicera japonica* Thunb. Ebinger 12223. *Lonicera sempervirens* L.

Ebinger 7679. *Lonicera tatarica* L. Ebinger 10289. *Lonicera xylosteum* L. Ebinger 8218.

CARYOPHYLLACEAE: *Agrostemma githago* L. Sampson 905. *Saponaria vaccaria* L. Sampson 923. *Silene cucubalus* Wibel White 79.

CHENOPODIACEAE: *Atriplex patula* L. Ebinger 7321. *Chenopodium berlandieri* Moq. Ebinger 9176. *Salsola pestifer* A. Nels Ebinger 5721.

COMPOSITAE: *Antennaria neglecta* Greene Moore 25. *Arctium lappa* L. Sargent & Henderson s.n. *Arctium minus* (Hill) Bernh. McClain 150. *Artemisia annua* L. Mertz 123. *Aster ericoides* L. Ebinger 4233. *Aster exiguus* (Fern.) Rydb. Burns 119. *Aster ontarionis* Wieg. Ebinger 10914. *Aster praealtus* Poir. Miller 84. *Bidens comosa* (Gray) Wieg. Moore 213. *Bidens polylepis* Blake Ebinger 5107. *Bidens vulgata* Greene Rayhill 77. *Cacalia tuberosa* Nutt. Sampson 4. *Carduus nutans* L. Thut s.n. *Centaurea cyanus* L. Ebinger 4630. *Cirsium arvense* (L.) Scop. Smeltzer 111. *Dyssodia papposa* (Vent.) Hitchc. Sargent s.n. *Echinops sphaerocephalus* L. Stover s.n. *Erechtites hieracifolia* (L.) Raf. Burns 34. *Erigeron strigosus* Muhl. Ebinger 4351 *Helianthus annuus* L. Henderson 179. *Helianthus decapetalus* L. Moore 146. *Helianthus hirsutus* Raf. Ebinger 5108. *Hieracium scabrum* Michx. Thut s.n. *Liatris scabra* (Greene) K. Schum. Sij 24. *Polymnia canadensis* L. Ebinger 4787. *Rudbeckia laciniata* L. Ebinger 7875. *Rudbeckia subtomentosa* Pursh Ebinger 4801. *Senecio vulgaris* L. Ebinger 10426. *Solidago media* (Greene) Bush Sij 26. *Sonchus asper* (L.) Hill Ebinger 11808. *Tragopogon dubius* Scop. Ebinger 4418.

CONVOLVULACEAE: *Convolvulus arvensis* L. Ebinger 4563. *Cuscuta polygonorum* Engelm. Dolbeare 2903. *Ipomoea hederacea* Jacq. Crabill 49. *Ipomoea purpurea* (L.) Roth Burns 272.

CORNACEAE: *Nyssa sylvatica* Marsh Ebinger 6032.

CRASSULACEAE: *Sedum ternatum* Michx. Ebinger 10709.

CRUCIFERAE: *Alliaria officinalis* Andrz. Ebinger 4405. *Arabis shortii* (Fern.) Gleason Ebinger 4277. *Arabis virginica* (L.) Poir. Ebinger 5279. *Brassica nigra* (L.) Koch Ebinger 4562. *Descurainia sophia* (L.) Webb McClain 229. *Hesperis matronalis* L. Ebinger 5466. *Lepidium densiflorum* Schrad. Ebinger 4426. *Sisymbrium altissimum* L. Ebinger 5719.

CUCURBITACEAE: *Sicyos angulatus* L. Ebinger 7887.

DIPSACACEAE: *Dipsacus sylvestris* Huds. Ebinger 7158.

EUPHORBIACEAE: *Acalypha deamii* (Weatherby) Ahles Ebinger 7941. *Acalypha ostryaefolia* Riddell Thut s.n. *Euphorbia cyparissias* L. Phipps s.n. *Euphorbia marginata* Pursh Iytalis 70.

FAGACEAE: *Quercus palustris* Muench. Moore 263.

FUMARIACEAE: *Dicentra canadensis* (Goldie) Walp. Ebinger 9394.

GENTIANACEAE: *Gentiana flavida* Gray Ebinger 7914. *Gentiana puberula* Michx. Ebinger 6842.

HALORAGACEAE: *Myriophyllum spicatum* L. Ebinger 10462.

HYPERICACEAE: *Hypericum prolificum* L. Stover s.n.

LABIATAE: *Lamium amplexicaule* L. Diel s.n. *Leonurus cardiaca* L. Ebinger 7317. *Lycopus americanus* Muhl. Moore 207. *Mentha cardiaca* Gerarde ex Baker Arzeni s.n. *Nepeta cataria* L. Thut s.n.

Scutellaria parvula Michx. Thut s.n. *Stachys hispida* Pursh Eytalis 15.

LEGUMINOSAE: *Astragalus canadensis* L. Ebinger 5791. *Baptisia leucantha* T. & G. Ernst s.n. *Baptisia leucophaea* Nutt. Ebinger 4361. *Cassia marilandica* L. Cravey s.n. *Coronilla varia* L. Ebinger 8503. *Desmanthus illinoensis* (Michx.) MacM. Ebinger 4575. *Desmodium rotundifolium* DC. Ebinger 10707. *Lathyrus latifolius* L. Eytalis 71. *Lathyrus myrtifolius* Muhl. Sampson 1171. *Lespedeza cuneata* (Dum.-Cours.) G. Don Ebinger 10956. *Lespedeza thunbergii* (DC.) Nakai Ebinger 10955. *Lotus corniculatus* L. Ebinger 4647. *Petalostemum candidum* (Willd.) Michx. Sampson 1128a. *Robinia pseudoacacia* L. Moore 226. Strophostyles helvola (L.) Britt. Thut s.n. *Vicia villosa* Roth Ebinger 10433.

LINACEAE: *Linum perenne* L. Thut & Diel s.n. *Linum usitatissimum* L. Ebinger 7604.

MALVACEAE: *Abutilon theophrasti* Medic. Poole 89. *Althaea rosea* (L.) Cav. Ebinger 7605. *Hibiscus militaris* Cav. Ebinger 7862. *Hibiscus trionum* L. Ebinger 7320.

MORACEAE: *Morus alba* L. Ebinger 4614.

NELUMBONACEAE: *Nelumbo lutea* (Willd.) Pers. Ebinger 10975.

NYMPHAEACEAE: *Nuphar advena* Ait. Ebinger 11063.

OLEACEAE: *Fraxinus lanceolata* Borkh. Ebinger 7367. *Ligustrum vulgare* L. Ebinger 6841.

ONAGRACEAE: *Gaura parviflora* Dougl. Stover s.n. *Jussiaea repens* L. Ebinger 10972. *Ludwigia alternifolia* L. Ebinger 5803. *Ludwigia palustris* (L.) Ell. Ebinger 11066. *Oenothera speciosa* Nutt. Sampson 1347.

PAPAVERACEAE: *Papaver somniferum* L. Stover s.n.

POLEMONIACEAE: *Phlox glaberrima* L. Sampson s.n.

POLYGONACEAE: *Polygonum erectum* L. Ebinger 9128. *Polygonum hydropiperoides* Michx. Ebinger 7864. *Polygonum lapathifolium* L. Thut s.n. *Polygonum longisetum* De Bruyn Gerlach 71. *Polygonum ramosissimum* Michx. Ebinger 7909. *Rumex obtusifolius* L. Winslow 59.

PRIMULACEAE: *Anagallis arvensis* L. Roberts s.n. *Lysimachia nummularia* L. Ebinger 4384.

RANUNCULACEAE: *Anemone canadensis* L. Sampson 635. *Clematis pitcheri* Torr. & Gary Ebinger 11043. *Delphinium tricorne* Michx. Ebinger 6142. *Hydrastis canadensis* L. Stover s.n. *Ranunculus fascicularis* Muhl. Ebinger 6184. *Ranunculus longirostris* Godr. Ebinger 11070. *Thalictrum hypoglaucum* Rydb. Thut, Pippen, & Bell s.n.

RHAMNACEAE: *Rhamnus cathartica* L. Ebinger 4380.

ROSACEAE: *Malus pumila* Mill. Mueller 803. *Rosa setigera* Michx. Thut, McGinnis, & Pixley s.n.

RUBIACEAE: *Galium obtusum* Bigel. Ebinger 4363.

SALICACEAE: *Populus alba* L. Ebinger 4486. *Populus grandidentata* Michx. Ebinger 6625.

SANTALACEAE: *Comandra umbellata* (L.) Nutt. Ebinger 4365.

SAXIFRAGACEAE: *Mitella diphylla* L. Sampson s.n.

SCROPHULARIACEAE: *Castilleja coccinea* (L.) Spreng. Sargent s.n. *Chaenorrhinum minus* (L.) Lange Ebinger 4572. *Chelone obliqua* L. Ebinger 10915. *Leucospora multifida* (Michx.) Nutt. Ebinger 10970. *Linaria vulgaris* Hill Ebinger 7602. *Lindernia dubia* (L.) Pennell Ebinger 7873. *Pedicularis canadensis* L. Arzeni s.n. *Verbas-*

cum virgatum Stokes Ebinger 7312. *Veronica persica* Poir. Mertz 171.

SIMARUBACEAE: *Ailanthus altissima* (Mill.) Swingle Ebinger 4645.

SOLANACEAE: *Lycium halimifolium* Mill. Ebinger 6627. *Solanum dulcamara* L. McClain 294.

ULMACEAE: *Ulmus pumila* L. Ebinger 6800.

UMBELLIFERAE: *Conium maculatum* L. Dolbeare 2801. *Heracleum lanatum* Michx. Ebinger 5465. *Zizia aurea* (L.) Koch Ebinger 4350.

VALERIANACEAE: *Valeriana pauciflora* Michx. Ebinger 7608.

VERBENACEAE: *Verbena bracteata* Lag. & Redr. McClain 276. *Verbena hastata* L. Ebinger 5802. *Verbena simplex* Lehm. Ebinger 7313.

VITACEAE: *Vitis cinerea* Engelm. Ebinger 7664.

ZYGOPHYLLACEAE: *Tribulus terrestris* L. Phillippe 841.

MONOCOTYLEDONEAE

ALISMACEAE: *Sagittaria brevirostra* Mack. & Bush Dolbeare 2902.

CYPERACEAE: *Carex lanuginosa* Michx. Ebinger 10456. *Cyperus filiculmis* Vahl Ebinger 10461. *Eleocharis engelmanni Steud.* Stover s.n. *Scirpus acutus* Muhl. Sampson 166. *Scirpus smithii* Gray Ebinger 10965.

GRAMINEAE: *Aristida longespica* Poir. Moore 321. *Avena sativa* L. Ebinger 10427. *Bromus latiglumis* (Shear) Hitchc. Ebinger 7849. *Muhlenbergia glabriflora* Scribn. Furrey 100. *Panicum lindheimeri* Nash Moore 322. *Panicum miliaceum* L. Ebinger 10431. *Paspalum circulare* Nash Moore 302. *Poa annua* L. Ebinger 7437. *Setaria verticillata* (L.) Beauv. Warner s.n. *Sorghum vulgare* Pers. Ebinger 5867.

IRIDACEAE: *Belamcanda chinensis* (L.) D.C. Brown 137.

LEMNACEAE: *Spirodela polyrhiza* (L.) Schleid. Ebinger 11065. *Wolffia columbiana* Karst. Ebinger 10554.

LILIACEAE: *Hemerocallis fulva* L. Ebinger 7606. *Hemerocallis flava* L. Ebinger 10428. *Lilium tigrinum* Ker Bowen 155. *Yucca filamentosa* L. Ebinger 12220.

NAIADACEAE: *Naias quadalupensis* (Spreng.) *Magnus* Ebinger 10971.

ORCHIDACEAE: *Corallorhiza odontorhiza* (Willd.) Nutt. Winslow 124.

POTAMOGETONACEAE: *Potamogeton pusillus* L. Dolbeare 2985.

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EFFECT OF MESH SIZE ON TRAP CAPTURE OF LARGEMOUTH BASS

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ABSTRACT.—Evidence is presented that traps made of coarse mesh netting are better than traps made of fine mesh for capture of largemouth bass over 12 inches long. An attempt is made to explain the selective action of mesh size in terms of net visibility as it might affect fish entering traps, and also those trying to escape from traps following capture.

Introduction

In late May 1941, I set trap nets of three mesh sizes at Lake Springfield, Sangamon County, Illinois, and found that the larger sizes of largemouth bass, *Micropterus salmoides,* Lacepede, were caught more successfully in coarse mesh traps than in fine mesh traps. This tendency has been reported in the trap net fishing for carp and buffalo, but it has not been described in fishing for bass. The opposite tendency has been reported in a number of sportfish species.

Methods and Materials

The traps used at Springfield were wing nets (also referred to as fykenets and hoopnets), and were of three mesh sizes: "fine"-1 x 1-inch (25 x 25mm), square mesh, "intermediate" -1½ x 1½-inch (38 x 38mm), and "coarse" -2½ x 2½-inch (63 x 63mm). Trap diameters (heights) varied from 2½ feet (0.77m) to 4½ feet (1.37m), but these moderate differences in diameter have been disregarded in presenting the catch data. A 1½ x 1½-inch square mesh, lead net, 60 feet (18.3m). long, 3½ feet (1.07m) deep was used with each trap, irrespective of the mesh of the trap. The traps were set in water deep enough to cover, or almost cover, the largest hoops comprising the net support.

The fish taken in the traps were measured in inches to the nearest 1/10 inch (2½mm), total length, then assigned to the nearest ½-inch size class.

Following measurement of the fish they were returned to the water near the nets in which they were caught. With the possible exception of a single bass specimen 12.0 inches long (305mm) all of the bass represented in the tables were large enough to have been caught by any of the traps used, i.e. they could not slip through the meshes of the coarsest nets fished when the nets were stretched tight. Only one bass less than 12.0 inches was caught during the two weeks of trapping -a 7.0 inch bass was caught in one of the fine mesh traps.

Sechii disc readings, measured in inches, showed that the water at the time of the trap collections was fairly turbid. At Bird Haven the reading was 6 inches (0.15m) on May 14, and 12 inches (0.3m) on May 20. At Toronto the reading was 8 inches (0.2m) on May 20, and at Woodside 6 inches (0.15m) on May 23.

Results

The numbers of bass, 12 inches and larger, caught each day in individual traps of the three mesh sizes are shown in Table 1. Based on these data the average catch rates for the

two weeks of fishing came out as follows: 0.08 bass per trap in the fine mesh traps, 0.33 per trap in the intermediate mesh traps, and 0.64 per trap in the coarse mesh traps. These averages were obtained from 34, 6 and 28 lifts of the fine, intermediate, and coarse nets respectively. The better results with the coarse nets can be seen from day to day as well as for the entire two week period.

The bass caught at Springfield ran to large sizes. The 3 bass caught in the fine nets measured 12, 15.5 and 18 inches (305, 394, and 475-mm), total length; the two bass caught in the intermediate net measured 18.5 inches (470mm) each; the 18 bass caught in the coarse nets measured 17-19 inches (432-483-mm).

At each of the three fishing sites

TABLE 1. Number of largemouth bass, 12.0 inches (305 mm), and larger, caught in individual trap nets of three mesh sizes, fine (F), intermediate (I), and coarse (C) on successive lifts at various sites in shallow water, Lake Springfield, May 1941.

Fishing site	Trap identification number	Square mesh size 1	Dates of trap lifts — May 14	15	16	19‡	20	21	22*	23‡	26+
Bird Haven Bay	11	F			–	–	–				
	12	F			–	–	–				
	5	C	–	2	–	2	1				
	6	C	2	1	–	–	1				
Boy Scout Camp Bay	3	F	–	–	–	–					
	4	F	–	–	–	–					
First Bay East of Boy Scout Camp	1	F	–	1	–	1					
	2	C	–	–	4	1					
Near IC Railroad crossing, north side	8	F			–	–	–	–	–		–
	10	I			–	–	–	–	1		1
	7	C			–	1	–	2			
	9	C			–	–	–	1			
Lincoln Gardens	3	F					1	–			
	4	F					–	–			
Toronto	1	F					–		–		
	2	C					–		–		
Woodside	11	F								–	
	12	F								–	
	5	C								–	
	6	C								–	
Press Club	3	F									–
	4	F									–
	7	C									–
	9	C									–

1 For actual mesh sizes, see text.
* The two traps lifted at I.C. crossing had been fished 24 hours; those at Toronto for 48 hours.
\+ All traps fished 48 hours.
‡ All traps fished 72 hours.

where bass were taken in numbers, (at Bird Haven, at the Bay east of the Boy Scout Camp, and at the I. C. Bridge, the best results were achieved with the coarse nets. This obviously suggests that the difference in catch rate was due more to mesh size than to trap placement. Evidence of selectivity of mesh is also shown in the consistency with which the large bass were caught in the traps of different mesh. Bass 12 inches or longer were taken in 12 of the 28 lifts of the coarse mesh traps (43 percent), in 2 of 6 lifts of the intermediate mesh traps (33 percent), but in only 3 of 34 lifts of the fine mesh traps (9 percent).

DISCUSSION

It appears from the data presented that largemouth measuring 12 inches and larger belong with the large sizes of certain commercial species which Starrett and Barnickol (1955) listed as fish that were caught better in coarse mesh nets, namely 15 inch and larger sizes of carp, bigmouth buffalo, and smallmouth buffalo. While Starrett and Barnickol concluded that coarse nets were inferior to fine nets for capture of sportfishes of desirable sizes (sizes generally acceptable to sport fishermen), some of the fish given the "desirable" rating were almost certainly small enough to have escaped through the meshes of the coarse mesh nets, for example 8.0 inch white crappies and black crappies, and 15.0-inch channel catfish. Thus, the degree of selectivity of their nets for capture of crappies and channel catfish remains uncertain.

It is suspected -and this is a commonly held belief of net fishermen- that nets of finer mesh are more easily seen by fish approaching them, and therefore that fine mesh nets are easiest for fish to avoid. It should also be noted that captured largemouth bass and certain other species are capable of escaping from traps through the funnels (Hansen, 1944, Patriarche, 1968). Fine mesh nets should be easiest to escape from because of the greater contrast between the opening at the apex of the funnel (the escape route) and the net material of which the funnels are made. Differences in mesh sizes might have little effect on captures and escapes in clear water but have a decided effect on both in turbid waters, (the situation at Lake Springfield). At Lake Glendale the best catch rates of bass in wingnets were made in early spring (March) when the water was turbid, Hansen (1953), though in that study it was not certain that low water temperature, or some other seasonal factor had not affected the catch as much as high turbidity. Mesh size probably would not affect the capture of fish at night, but in turbid water could affect the number of escapes with the coming of daylight.

Fine mesh traps nearly always catch more species and more individual fish than coarse mesh traps because they can retain fish of a wider size range. The buildup of trapped fish in fine mesh traps is a possible factor affecting the desire of large sized fish to enter traps or avoid entrance, and also may be a factor in the desire of large fish to escape or remain in the traps after capture.

Large as well as small bass were captured in quantity in fine mesh traps at Lake Glendale when the lake was between 2 and 5 years old, Hansen (1966), and this has been observed when fine mesh nets were fished in a number of other new Illinois lakes. Lake Springfield was approximately 6 years old at the time of the 1941 trapping. Bass of all sizes are generally trapped with difficulty with fine mesh nets in old lakes. It is in older lakes that the

use of coarse mesh nets might prove especially useful in population sampling or in obtaining large bass to meet special needs.

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GASTROTRICHA FROM ILLINOIS

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ABSTRACT.—Twelve species of gastrotrichs from Illinois are recorded; four species are described and figured. They are: *Chaetonotus macrochaetus, C. quintospinosus, Heterolepidoderma gracile* and *H. ocellatum.* These four species have not been previously recorded in the North American published literature.

Freshwater gastrotrichs of apparently identical or similar species have been reported from widely separated areas of the earth, but few geographic or political areas have been systematically studied for their occurrence. Michigan (Brunson, 1950) and Illinois (Robbins, 1963) are the only states of the United States that have been extensively surveyed for the presence of gastrotrichs.

In the Illinois study at least one collecting station was established in each county of the state. Temporary and permanent, lotic and lentic waters were sampled. Twelve species of gastrotrichs were found. They are: *Chaetonotus acanthophorus, C. aculeatus, C. longispinosus, C. macrochaetus, C. octonarius, C. quintospinosus, C. spinulosus, C. trichodrymodes, Heterolepidoderma gracile, H. illinoiensis. H. ocellatum,* and *Lepidodermella squamatum.* Distributional data for the species cited above will be furnished by the author on request.

Most of the collections for this study were made during the years 1961 to 1963, but collecting was continued during summer seasons until 1968. Horlick (1969) has since established the presence of additional species and genera of gastrotrichs in his study of selected areas of northeastern Illinois. Previous reports of gastrotrichs in Illinois are those of Goldberg (1949) and Sacks (1955), both of whom found *Lepidodermella squamatum.*

Materials and methods for the collection and observation of gastrotrichs are those described by Robbins (1965).

This paper presents figures and descriptions of four species previously known, but undescribed in the published literature as North American forms.

Descriptions

Chaetonotus macrochaetus Zelinka, 1889

Plate I, Figs. 1 and 2

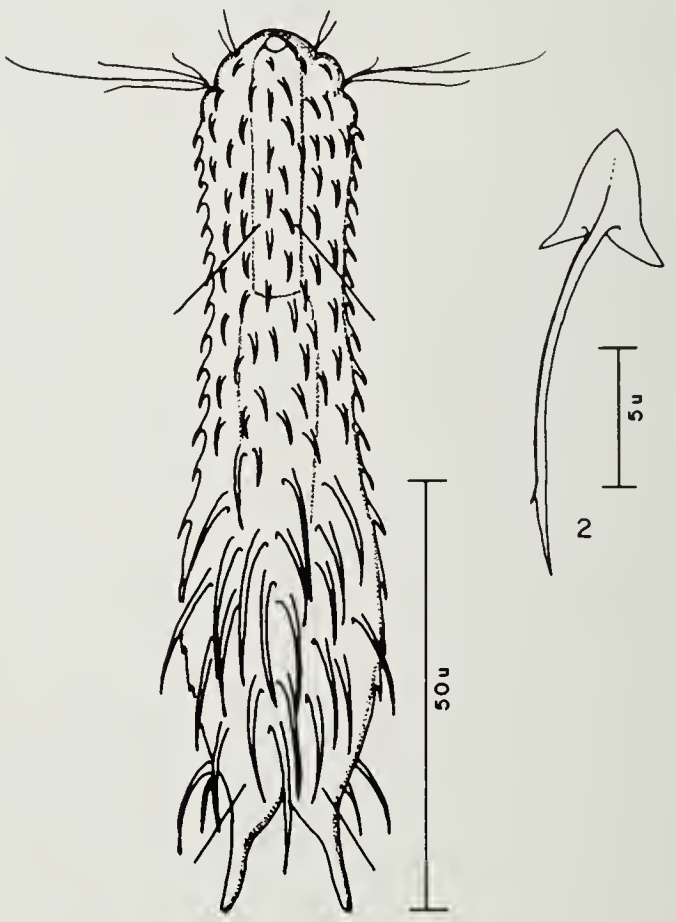

PLATE I

Fig. 1. Dorsal aspect of *Chaetonotus macrochaetus.*

Fig. 2. Single spine-bearing scale of *C. macrochaetus.*

Total length, 77μ-105μ; head width, 18μ; neck width, 13μ; trunk width, 23μ; pharynx length, 30μ; caudal furca length, 16μ; short spine length, 6μ; long spine length, 16μ-18μ; all spines minutely bifurcate, originate in scales, and arranged in nine to ten indistinct longitudinal rows; spines on trunk three times the length of those on head and neck; five lobed head; anterior and posterior pairs of tactile bristles present.

Specimens from Illinois identified as *C. macrochaetus* are identical to those described from Europe, except that the spines of the Illinois forms are twenty per-cent shorter.

Chaetonotus quintospinosus
Greuter, 1917

Plate II

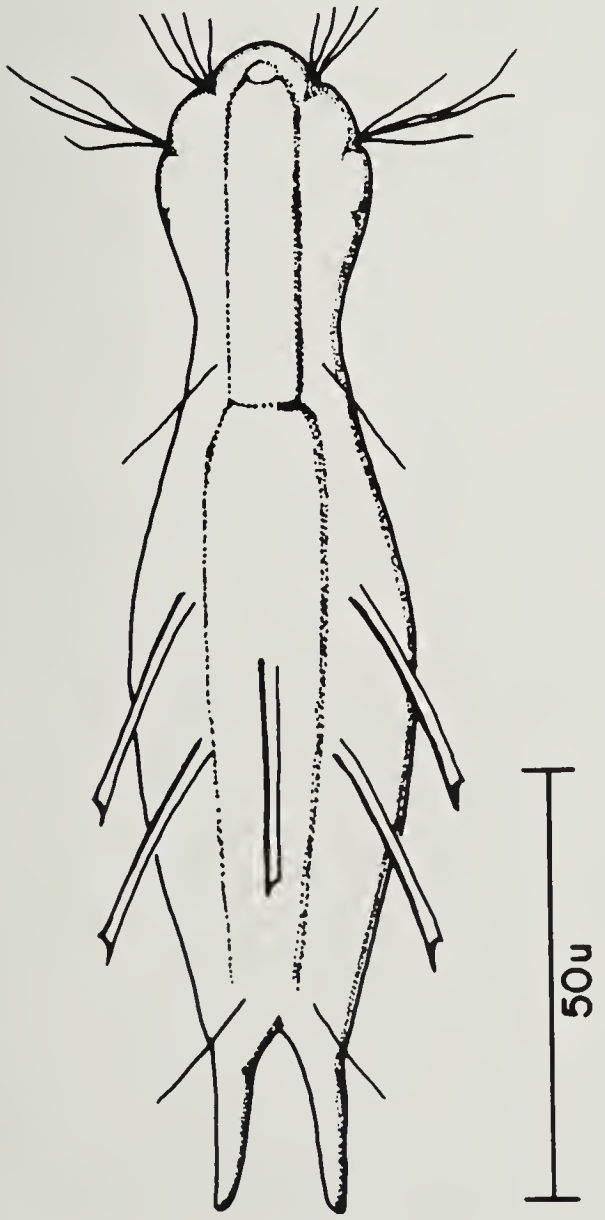

PLATE II

Dorsal aspect of *Chaetonotus quintospinosus.*

Total length, 130μ-135μ; head width, 22μ; neck width, 14μ; trunk width, 32μ; pharynx length, 36μ; caudal furca length, 19μ; spine length, 24μ; five moveable bifurcate spines on trunk; five lobed head; scales absent; anterior and posterior pairs of tactile bristles present.

Chaetonotus trichostichodes Brunson, 1950 is also a five spined form; unlike *C. quintospinosus,* the spines are arranged in a single transverse row on the anterior portion of the trunk.

Specimens from Illinois are thirty per-cent larger than those described from Europe: they are otherwise identical.

Heterolepidoderma gracile
Remane, 1927

Plate III, Figs. 1 and 2

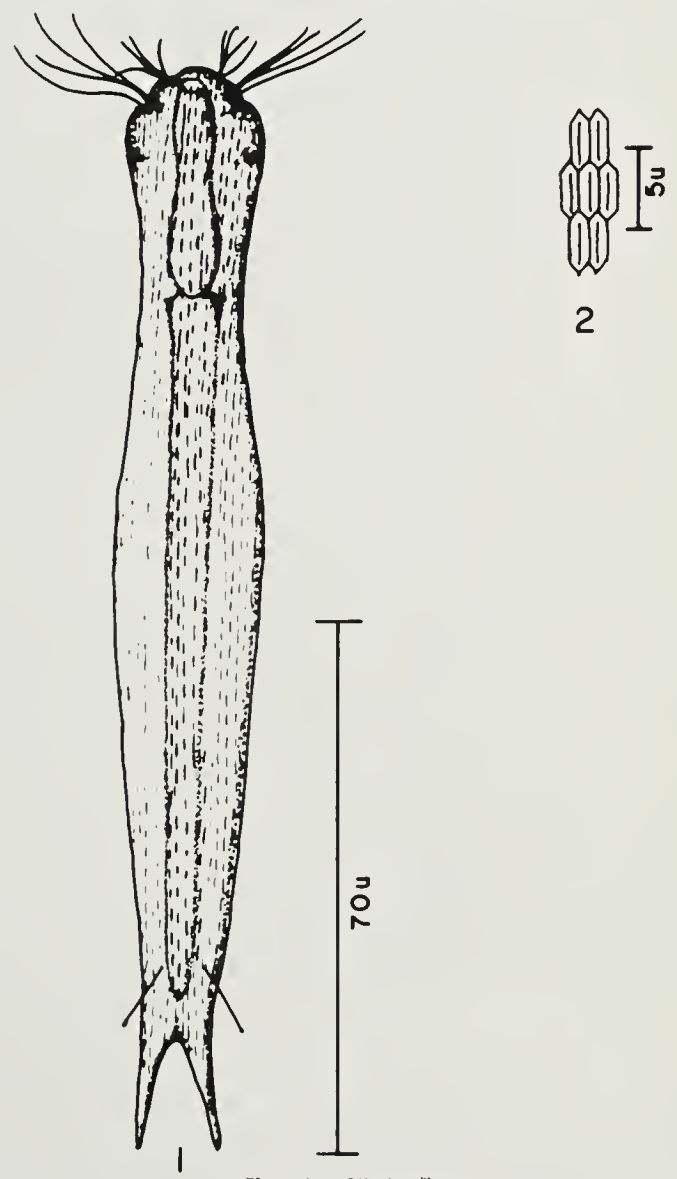

PLATE III

Fig. 1. Dorsal aspect of *Heterolepidoderma gracile.*

Fig. 2. Keel-bearing scales of *H. gracile.*

Total length, 140μ-150μ; head width, 18μ; neck width, 14μ; trunk width 20μ; pharynx weakly double bulbed, 28μ long; caudal furca length, 16μ; hexagonal keeled scales, 3μ-5μ long, 1μ-2μ wide; scales arranged in twenty to twenty-five longitudinal rows of forty to forty-five scales each; five lobed head; posterior pair of tactile bristles present.

Specimens from Illinois are approximately sixteen percent smaller and have more strongly developed head lobes than those described by Remane from Europe.

Heterolepidoderma ocellatum
(Metschnikoff, 1865)

Plate IV, Figs. 1 and 2

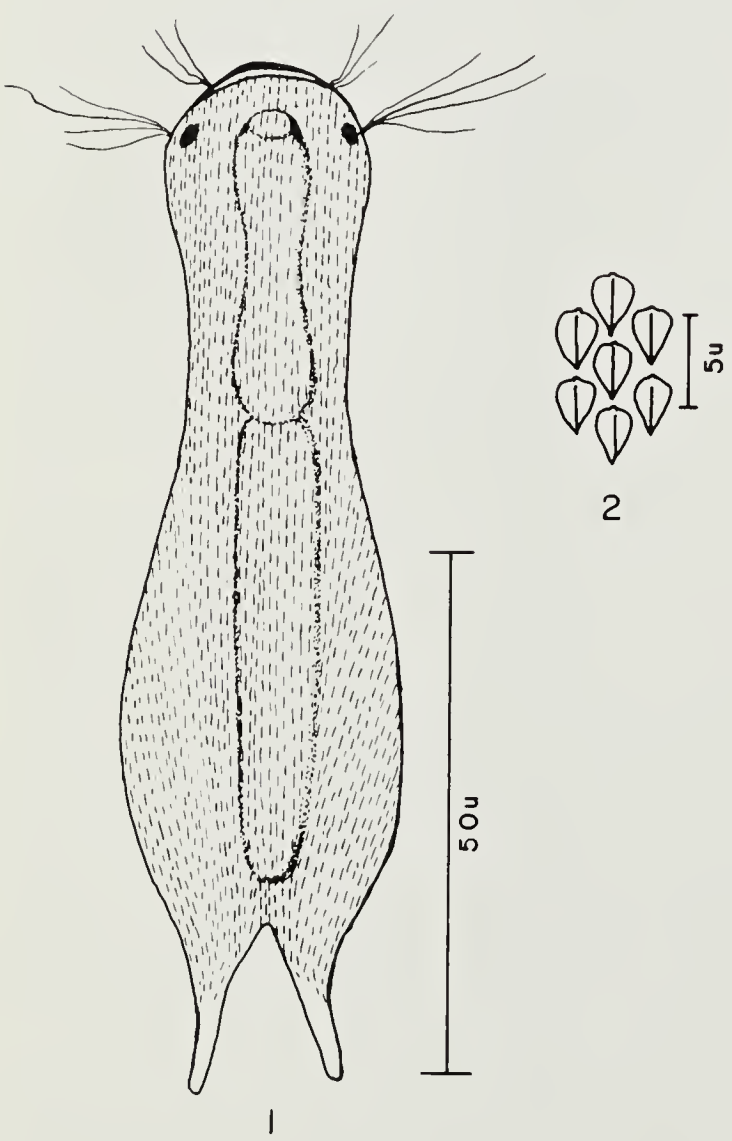

PLATE IV

Fig. 1. Dorsal aspect of *Heterolepidoderma ocellatum.*

Fig. 2. Keel-bearing scales of *H. ocellatum.*

Total length, 83μ-117μ; head width, 22μ; neck width 17μ; trunk width, 30μ; pharynx weakly double bulbed, 35μ long; caudal furca length, 21μ; subtriangular keeled scales, 2μ-4μ long, 1μ-2μ wide at base with apex directed posteriorly; scales arranged in twenty-five to thirty longitudinal rows of forty to fifty scales each; head broadly rounded; reddish refractile bodies on opposite sides of head; cuticle thickened at anterior margin of head; posterior pair of tactile bristles present.

The caudal furca of Illinois specimens is one-third longer than those described from Europe.

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Manuscript received August 27, 1973.

DR. BORIS MUSULIN

Dr. Boris Musulin died early Saturday morning, June 30, 1973, of injuries resulting from a collision with a "wrong-lane" driver on April 14, 1973. Both Dr. and Mrs. Musulin were hospitalized as a result of the accident which occurred on Illinois 13 between Carbondale and Murphysboro.

Dr. Musulin was born in Chicago on September 6, 1929, the son of Milan and Mary Palaska Musulin. He married Shelba Jean Choate of Carterville, Illinois, on August 12, 1961, and resided at 906 Skyline Drive Carbondale, Illinois. Fortunately Mrs. Musulin was not so seriously injured as Dr. Musulin and survives her husband.

Dr. Musulin received a Ph.B. in Chemistry with honors from Northwestern University in 1949 and a Ph.D. from the same University in 1954. In 1953-1954, he was a DuPont Research Instructor at the University of Minnesota; from 1954 to 1956 he was an Assistant Professor of Chemistry at Michigan State University; and in 1956 he came to Southern Illinois University as an Assistant Professor. He was promoted to Associate Professor in 1961 and to full Professor in 1969. In 1963-1964 he was a Visiting Associate Professor in the Theoretical Chemistry Institute at the University of Wisconsin.

During his professional career, Dr. Musulin attained an enviable reputation as a scientist. He is the author and/or co-author of some sixty articles printed in scientific journals here and abroad. These articles indicate a wide range of interests with a concentration in his specialty, quantum mechanics. He had an intense interest in data, numbers and calculations which he handled in a masterly manner. He is listed in many of the regional and national volumes containing biographical sketches, and he has been active in the affairs of state and national scientific societies. These include the Illinois State Academy of Science, the American Chemical Society, the Symposium of Molecular Structure and Spectroscopy, and the Winter Institute in Quantum Chemistry, Solid State Physics and Quantum Biology. He had a real interest in the Illinois State Academy of Science, serving as Chairman of the Chemistry Section in 1960, and as a most efficient Treasurer from 1967 to 1972. He was an active contributor to the *Transactions* of the Academy, was instrumental in establishing and supporting the "Student" sections, concerned about a sound financial structure, and convinced that the prestige of the Academy could, and should, be enhanced.

Dr. Musulin came to Southern Illinois University primarily to institute and develop a program in graduate physical chemistry. This he did and, as a result, the first M.S. and, later, the first Ph.D. in physical chemistry were granted to students whose research work was done under his direction. He also participated in teaching first-year chemistry as well as in undergraduate and graduate physical chemistry. He had a strong background and interest in physics and, at times, taught courses in the Department of Physics.

Outside of the field of science, Dr. Musulin's interests were wide and varied. He loved the outdoors; camping, canoeing and cycling, and was a member of a number of outdoor and wildlife societies. He loved the theater, especially Shakespeare, and the sports, especially when the Chicago teams were involved. In fact, he really loved and had a zest for

life. This was evidenced in the way he did things; with great enthusiasm and desire. With students, especially undergraduates with an interest in research in physical chemistry, Dr. Musulin would spend unlimited time and effort to advise, help, encourage, and perhaps prod them to greater effort. They will always remember him for his extra effort in their behalf and appreciate his concern for their welfare.

For those of us who knew him well, there now is a void which cannot be filled; we are glad to have known Dr. Musulin and mourn his untimely death.

K. A. Van Lente
Southern Illinois University
July 12, 1973

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